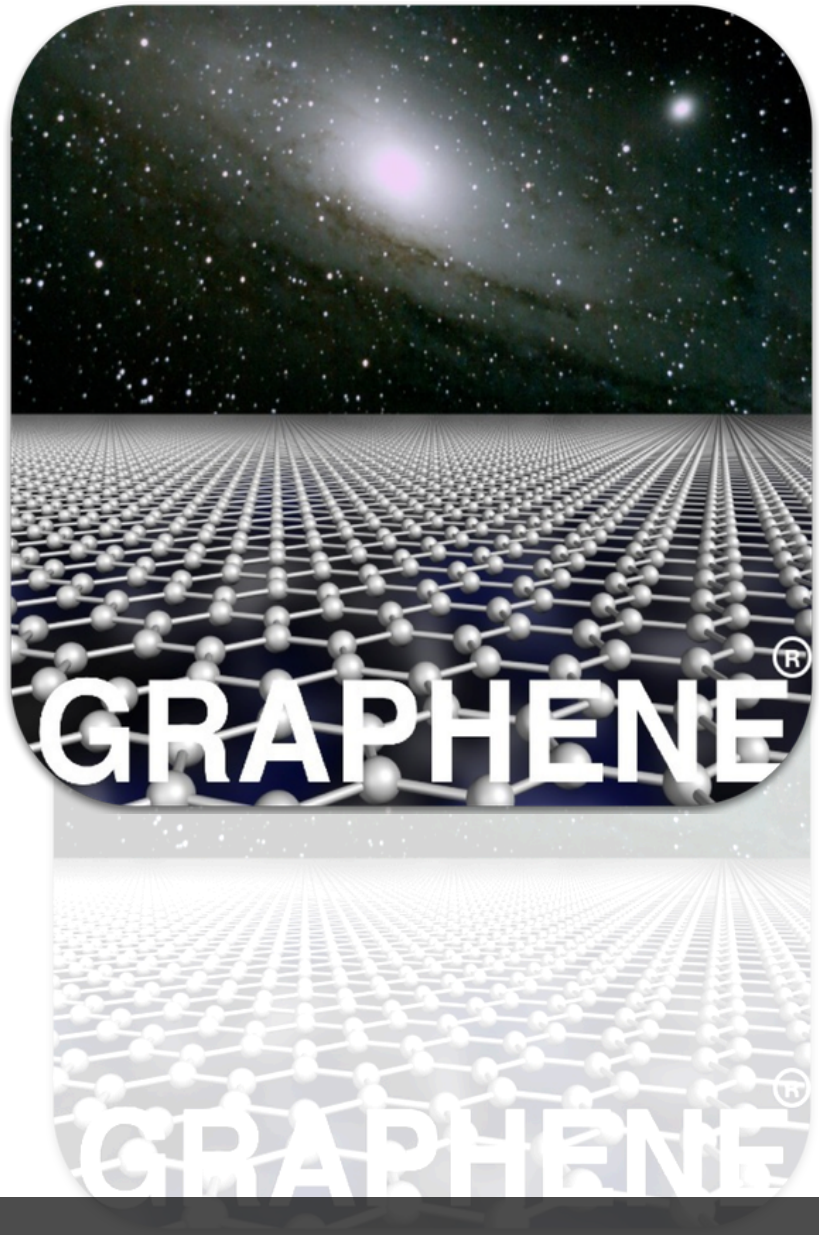


Label inspection

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Label inspection

in-the-Labeller Machine and at-the-Conveyor, with Cameras or Digital Photoscanners

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Informations on our analytic activities, audit, root cause analysis, contractual advice and design at: http://graphene-lda.com/designer-portal/index.html

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Electronic Inspection of Labels

Label Presence in-the-Machine, with Photoscanners
Label Presence at-the Conveyor, with Photoscanners
Label Position at-the Conveyor, with cameras

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Introduction

A single look to the Drinks' sale area of a shows a fact: today we are no more capable to imagine a container commercially successful without labels. From this basic observation derives the relevance of the Label inspection, the one devoted to assure that labels are present or correctly applied. Label inspectors are differentiated following the label detection principle and the place where the inspection is performed.

There are two distinct label inspection functioning principles:

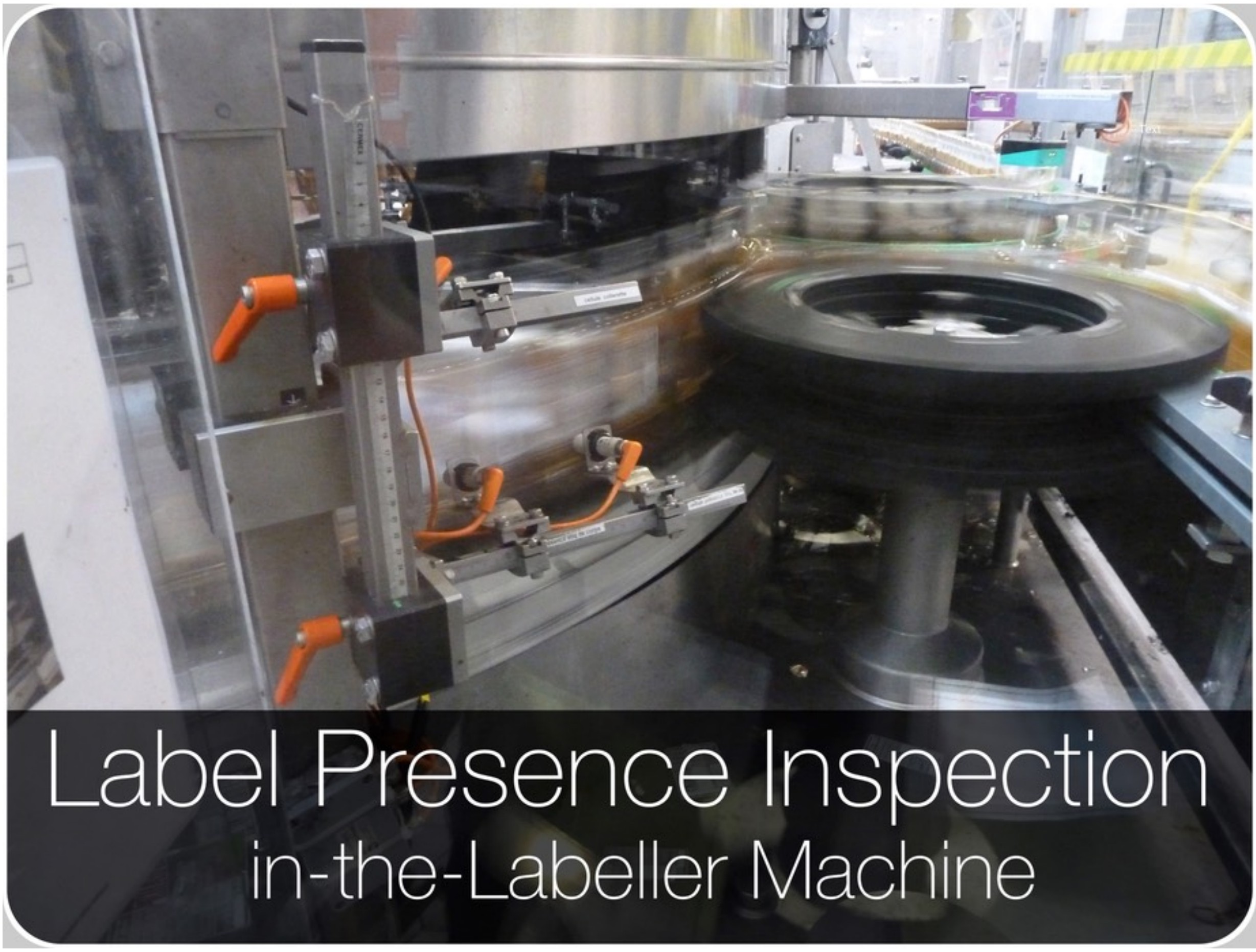
- luminous re-emission of the label surface, irradiated by a LED and later detected by an analog photo-sensor based on a photo-transistor (photoscanner);
- evaluation of CCD or CMOS camera images.

applied, alternatively:

- at-the-Conveyor;
in-the-Labeller Machine.

Graphene®

Food and Beverage Electronic Inspection Experts



Label Presence Inspection for body, back and neck labels *in-the-Labeller* Machine (Krones AG)

Where to establish a correlation

The best place to control labels' application is *in-the-Labeller* Machine, thus having the possibility of an early warning about the typical issue affecting all Labeller Machines: their Consecutive Faults. In this configuration, the photo-electric sensors have to be installed around the Labeller central carousel and after the rotary, prismatic-shaped brushes securing the labels' adherence to the container sidewall, immediately after each labeling station. Ideally, the label presence inspection should have to be immediately after a labelling station, so to let the Electronic Inspector feedback to the Labeller Machine automation, an earliest than possible warning signal about the fact its consecutive faults.

In the reality, this is rarely possible. All Labeller Machines have cams part of the central carousel, also projectually defining a reduced space where the labelled bottles are oriented toward the Label Presence Inspection photoscanners, like visible in the small figure below at right side.

Label Inspection



(../label_inspection.zip)

Flash animation, 45 MB, ZIP

After download click index.html

Consecutive Faults



(../label-inspection-.pdf)
(../../../../designer-portal/root-cause-analysis/root_cause_analysis_problem.pdf)

59 pages, 71 MB

(../label_inspection-2.epub)

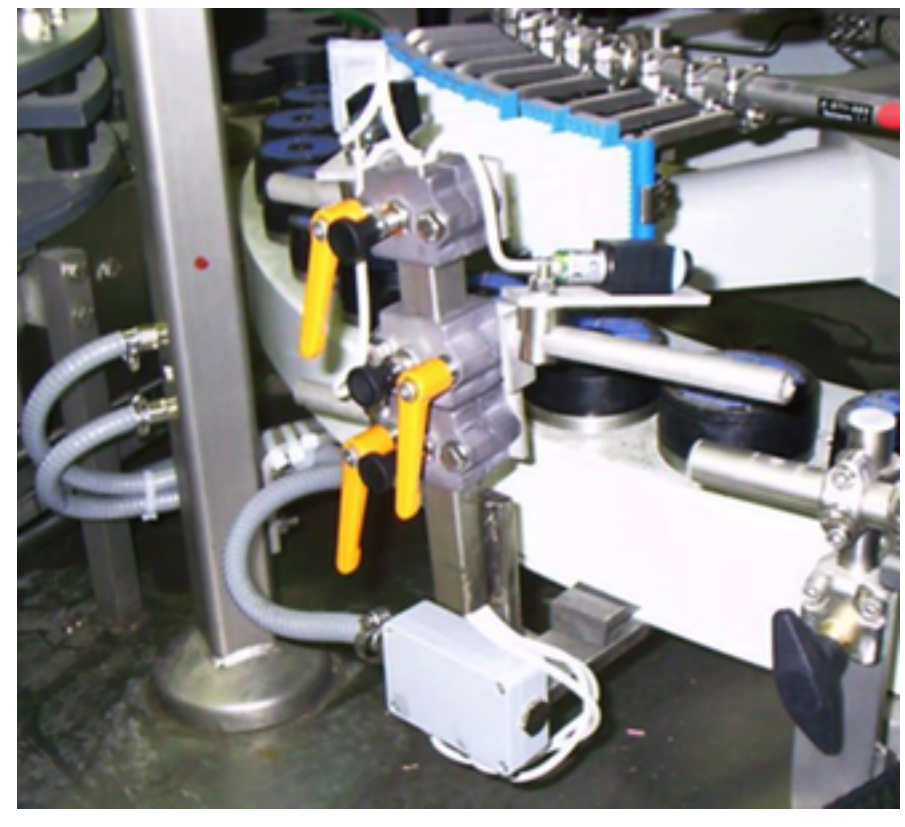


(../label_inspection-2.epub)

E-book 59 pages, 41 MB

A proper orientation of the bottles should have to be imposed by the cam immediately after each label application. Below at right side an example, showing one of these systems detecting the missing Neck-, Back- and Body-labels directly *in-the-Labeller Machine,* in a Carlsberg® Group Brewery. It provides this way a vital early *Stop Impulse* Signal with a delay minimised to a digital I/O card part of the Labeller Machine's PLC automation. Delay reduced to ≤2 mislabelled and rejected bottles.

A problem is however that the force exercised on the recently applied labels by the prismatic-shaped sponges securing the labels' adherence to the container sidewall, have the potential to let them flag or remove at all many of the incorrectly applied labels. Typically, those not sufficiently glued. We are speaking of labels uncorrectly applied, later lost but yet detected *Present* by the Electronic Inspector. Implying many non-labelled bottles later non rejected. Because of this reason, the majority of the Labeller Machines have the cam designed to revolve to the proper inspection angle all bottles only in the out feed of the carousel, immediately before the out feed starwheel, like visible in the figure above. When the inspection zone defined by the Labeller Machine's cam is immediately before its outfeed starwheel, it'll not be possible to have a truly *early Stop Impulse.* In this case, on the opposite we'll have *late Stop Impulse*, deriving by the Electronic Inspector's photoscanners installed immediately before the Labeller out feed starwheel.



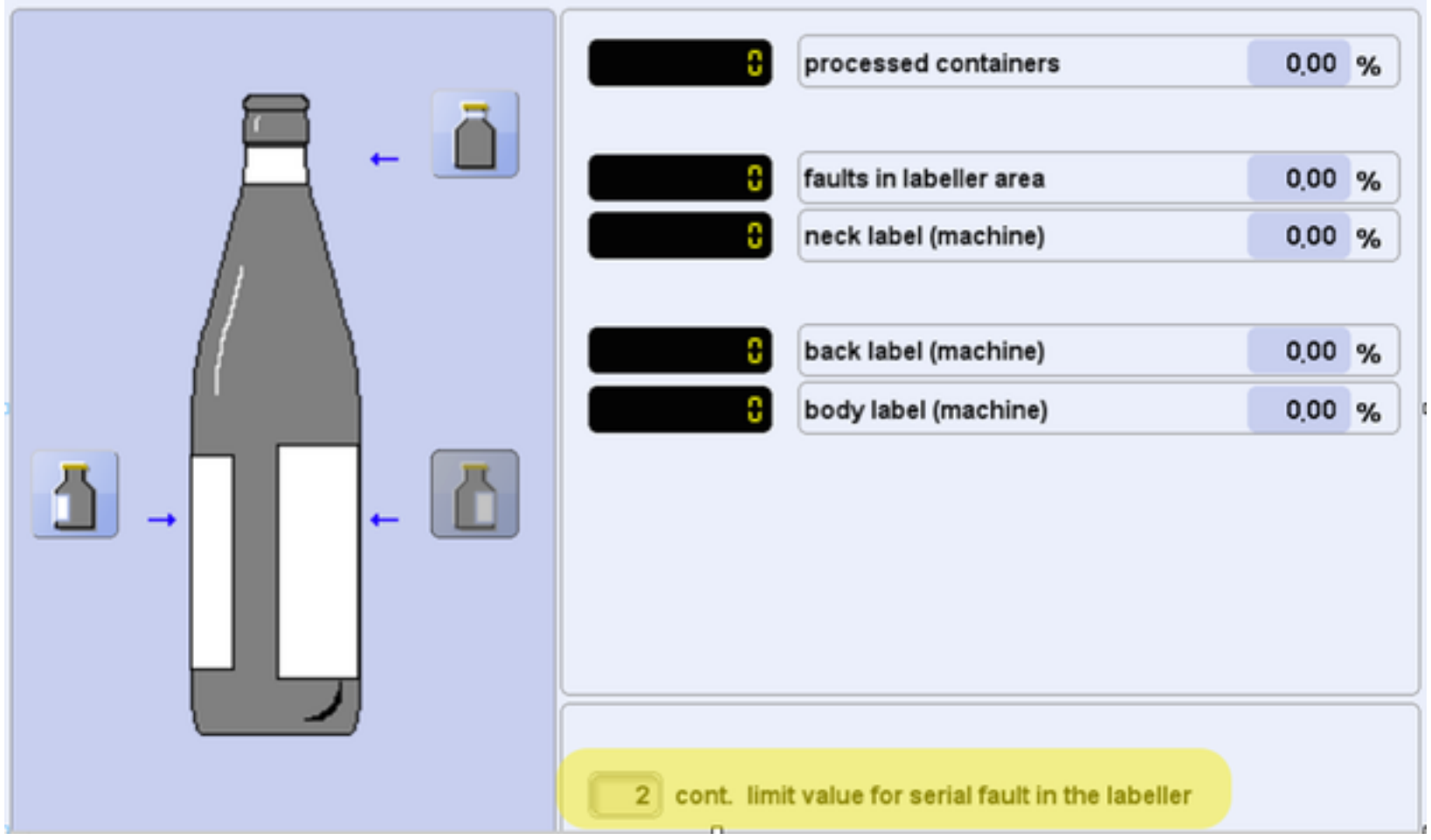
Body, neck and back label presence inspection analog photo sensors, installed in a Krones AG Labeller Machine. Hold by a single bracket allowing vertical movements referred to a (metallic) half-millimetric ruler (not visible in the picture). All of the cables passing thru metal bars, rather than exposed to bottles' hits, steam and glass splinters

Thus, meaning a delay ranging (5 ÷ 15) non-labelled rejected bottles. An amount of True Positives and consecutively rejected bottles proportional to Labeller Machine size and Production speed. A huge price, paid along the following 15 years, in terms of erroneously labelled bottles, clogging the Rejects Accumulation Table. Then also forcing a presence of human-Operators, that in many Countries is today extremely expensive.

Body, back, neck and all-around label presence inspections and positions. In evidence below a counter limit for serial faults. One key advantage of the Label Presence inspectors *in-the-Labeller* over the models *at-the-Conveyor.* To have the possibility of an extremely early warning of consecutive faults, as an example, 2-3 steps after label application, means possibility to stop automatically the Labeller by the Inspector, preventing losses on Production and downtimes

The fact that we are touching the subject of a proper inspection angle hints to the fact that there are also Labeller Machines whose Mechanical Designers are not fully aware of these strictly-Optoelectronic constraints. Constraints inherent to what angle and distance they have to exist between the Electronic Inpectors's photoscanners and the labelled bottles.

We have memory and records of cases where the Labeller's cam Design was clearly flawed, ignoring Optoelectronics:



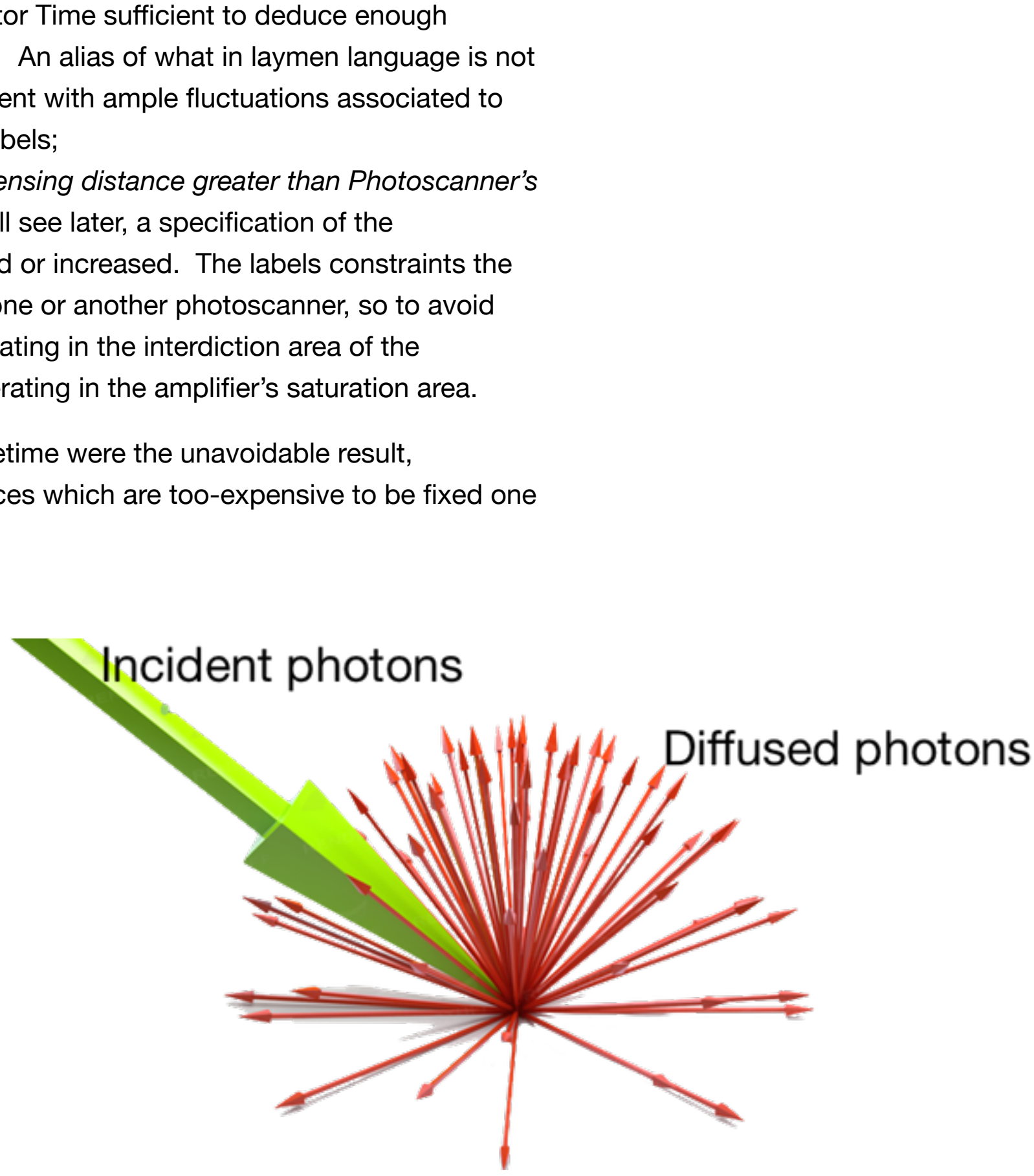
- Body
- Back
- Foil
- Neck
- Collar
- All-around
- Tamper-Evidence

- *erroneously skewed (≠ 90º) angles* from the label to the photoscanner's optic axe;
- *orientation angle correct but too-short label exposure to the photo-electric detector*, thus not giving to the Electronic Inspector Time sufficient to deduce enough random variables in the *sample space*. An alias of what in laymen language is not a “good measurement” or, a measurement with ample fluctuations associated to consecutive measurements of similar labels;
- *orientation angle correct only under a sensing distance greater than Photoscanner’s maximum.* Sensing distance is, as we’ll see later, a specification of the Photoscanner which cannot be modified or increased. The labels constraints the values of reflectivity forcing the use of one or another photoscanner, so to avoid under-exposure, oscillations when operating in the interdiction area of the amplifiers, or over-exposures when operating in the amplifier’s saturation area.

False Rejects along the following 15 years lifetime were the unavoidable result, corresponding to a kind of Design incoherences which are too-expensive to be fixed one time the Labeller Machine is commissioned.

How correlation is established

The incident photons emitted by a LED in the Photoscanner, green-coloured in the figure below at right side, interact with the label's or bottle's surface atoms, then forming secondary rays, in the example red-coloured. These secondary photons are reflected from the surface diffusely, scattered in all directions.



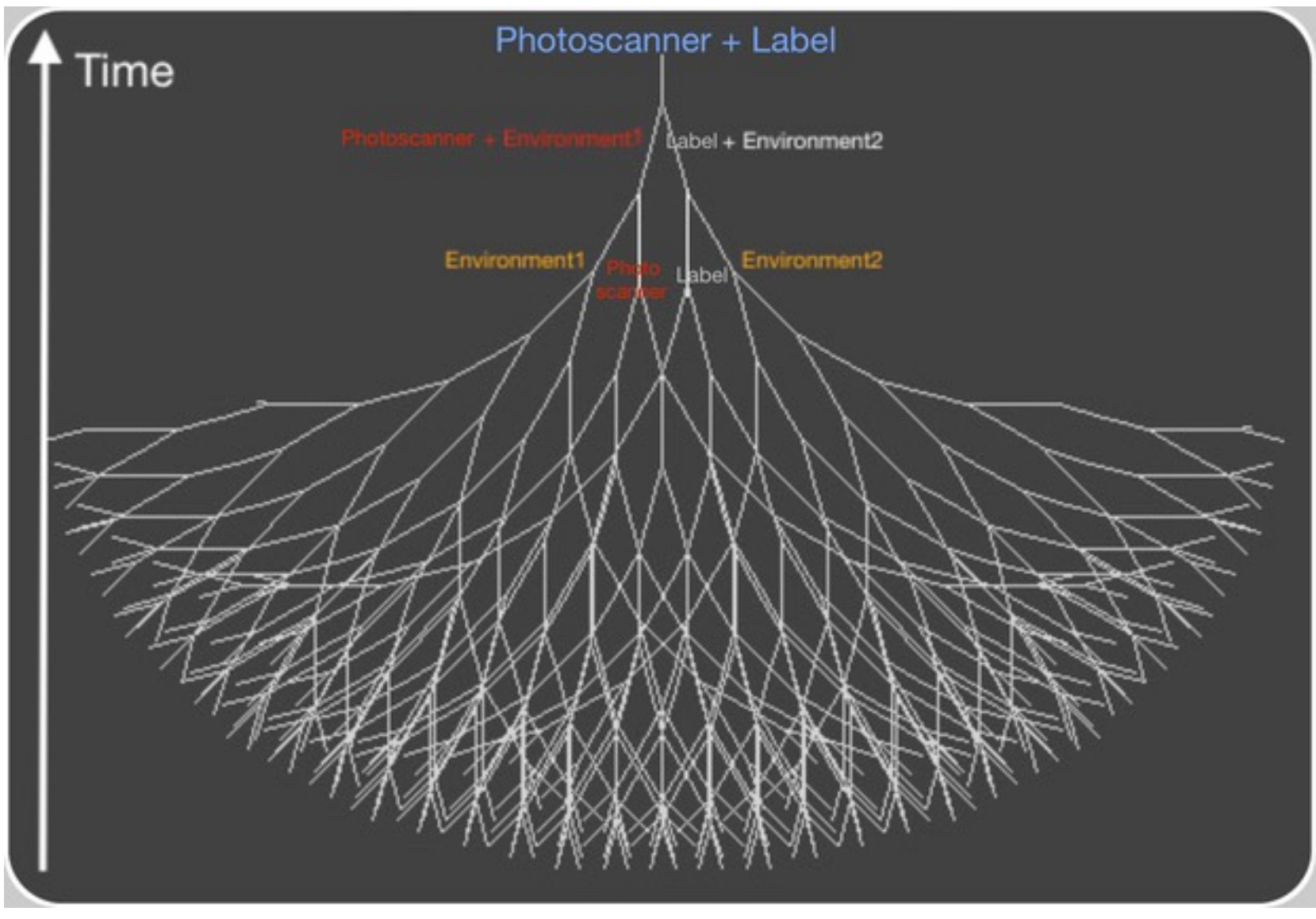
Ideally, following the cosine Law of Lambert, an illuminated diffuse reflecting surface will have equal luminance from all directions which lie in the half-space adjacent to the surface. A very small conical shaped fraction of them shall enter a photo-detector lying on side of the LED light source in the Photoscanner's plastic or metal case.

Diffusely reflected photons’ scattering (abridged by Renderstuff.com (http://renderstuff.com/vray-indirect-illumination-best-settings-cg-tutorial/)/2013)

Why so many False Rejects ?

Criticity of the Label-Photoscanner state

We saw with details elsewhere in this web site (../../../../services--technologies/physics-of-triggering/Trigger-Physics/index.html), how the measurement's steps to form a correlated *object-detector state*. As an example we'll try to determine if a bottle is labelled by mean of a common Photoscanner. Photoscanner including a LED illuminating the container's sidewall or neck, where the label is expected to be, later receiving and processing just a fraction of the retro-reflected diffused waves. Until switching its digital output if the retro-reflected waves' intensity is greater than a pre-defined threshold level.



(x-file:///Users/graphene/Documents/Graphene%C2%AE%20ver.%206.0.sandvox/Correlating_a_label_to_an_photoscanner_part_of_a_%20Label_Presence_inspection.jpeg)

To establish a relation between a label ("Label") and a Photoscanner ("Photoscanner"), both differentially related with the Environment ("Environment1", Environment2"), is necessary Time. Time to transform the previous *state*, in which all possible kinds of correlation of the Photoscanner coexist, in a following *state* in which the Photoscanner is "aware" to be correlated to a label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a cap. Quantomechanical explanation of the measurement process, unaffected by the circularities implicit in the classic explanations. The vertexes represent *interferences*

To definetely perceive a *correlated Label-Photoscanner State*, they are necessary:

1. **Time, to transform the previous state, in which all possible kinds of correlation of the Photoscanner coexist, in a following state in which the Photoscanner is "aware" to be correlated to a Label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a Label.** The correlation between the two systems, Photoscanner and Label, is progressively established during interaction and proportional to the natural logarithm (ln t) of the interaction time t. An ideal correlation, corresponding to a maximised information of the Photoscanner about the Label, can only be reached allowing an infinite time. The fact we cannot wait for an infinite time causes the measurements' fluctuations, a synonimous of the spectrum of the eigenvalues, resulting in the Electronic Inspector's false positives (false rejects). Time, for what ? To transform the previous state, in which all possible kinds of correlation (superpositions) of the Photoscanner coexist, in a following state in which the Photoscanner is *aware* to be correlated to a Label, because having recorded

eigenvalues for the eigenfunction Φ_{iS1} describing a Label.

2. **Interaction between the systems such that the information in the marginal distribution of the object inspected is never decreased**. In a probability distribution deriving by two random variables, we remember that *marginal distribution* is where we are only interested in one of them.

To detect a Label they are necessary Time and a way of interaction not reducing the information in the marginal distribution of the Label. In laymen words, an interaction not modifying the label. Label Presence photoscanners fulfill the second condition but a limit exists on the fulfillment of the first condition. It is the Labeller Machine's own cycle what decides how long Time is given to the Inspector's inspections. The limited Time becomes relevant when inspecting the presence of translucent labels. The red colour box evidentiates a mainly transparent label. Its reflective area is reduced to just a dark blue low-reflectivity area. A label like this requires the photoscanner directed at the clear text "CARLTON DRY", its only reflective area. As a consequence, it'll result impossible to detect flagging or inclined labels, rather just presence





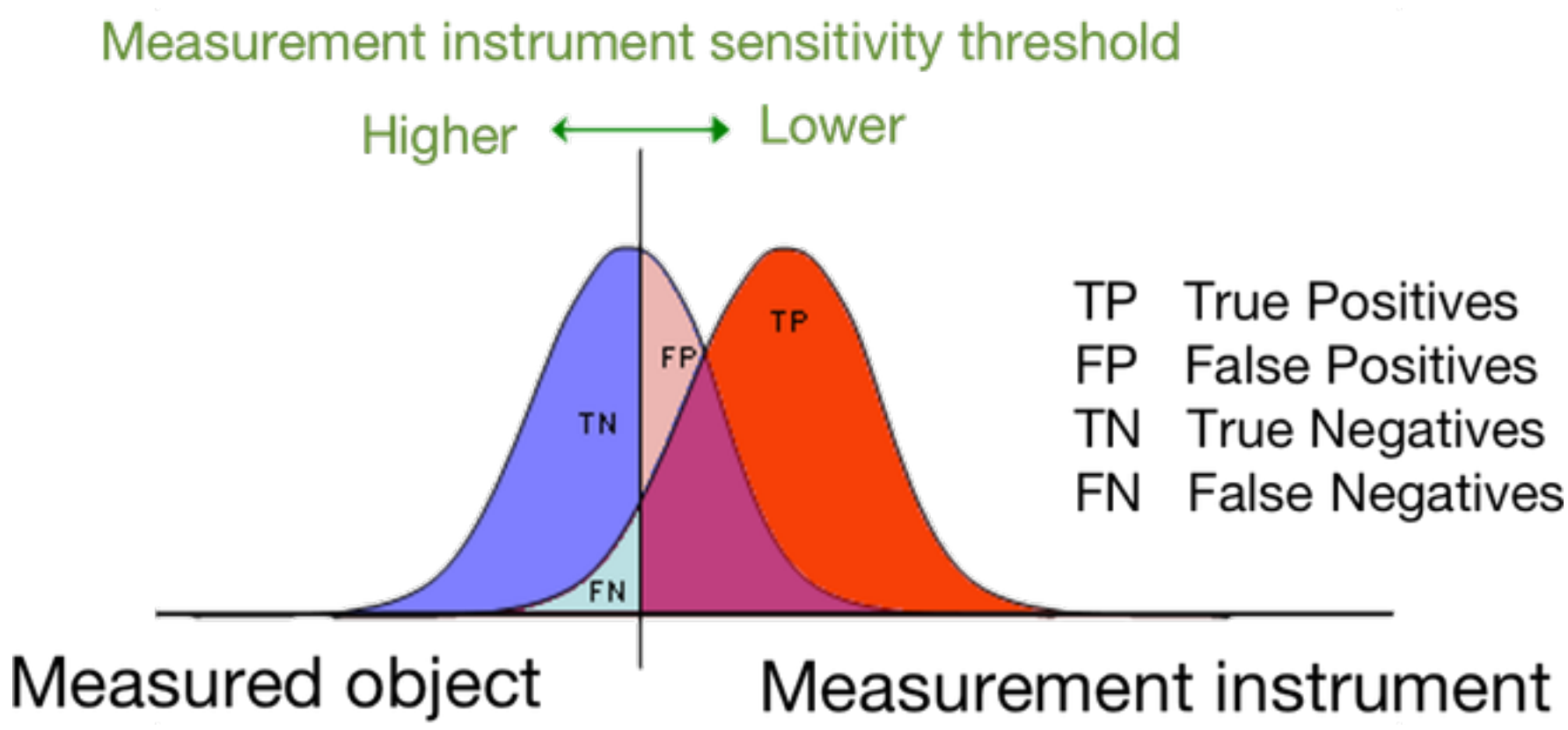
Otherwise, we'd have forced a reduction in the sample space of one of the random variables and then, we could not have any more *repeatability* of the measurements. As an example, this should be the case if we'd erroneously try to use a beam of high energy neutrons, rather than LEDs' low energy photons, to interact with the Label. The neutrons should modify the molecular structure of the Label, modifying its eigenstates and then the eigenvalues we expected to derive by the measurement.

What preceded is the true and unique scientific background existing for the fact that also double, triple or quadruple photoscanners, and also if of the best Quality (costing ~260 $ each), can result insufficient to reach satisfactory results. *Satisfactory* in terms of defects' rejection ratio with minimum false positives. Be wary of proposals for systems which could later leave only you and your Company with the nightmare to have the products' store, filled with yet palletised flagging-, malpositioned- or missing-labels.

Staff in the Beverage Bottling Halls knows what a near-nightmare is a store of pallets “contaminated” by many flagging-, missing or malpositioned-Labels (SABMiller plc, Poland, photo by T. Parker, OneRedEye, 2012)

Receiver Operating Characteristic analysis

ROC is a graphical plot adopted in the Signal Detection Theory and Statistics to illustrate the capability of a Binary Classifier system when its discrimination threshold is being varied. Binary Classifier because all of the existing *Electronic Inspectors*, also named *Bottling Controls* or more simply *Controls*, are part of the great family of the *Binary Classifiers*.



ROC-curve of a Label Presence Inspection. Imagine to process a statistically significative sample of bottles by mean of an *in-the-Labeller Machine* Electronic Inspector equipped with Label Presence Inspections. In the meantime, check one-by-one all rejects attributed to all its Label Presence Inspections, like its Body-, Back- and Neck-inspections. On the base of the Sensitivity threshold set in the photo-Detectors, they’ll arise their respective statistical distributions of the hits and of the misses, True Positives, False Positives, True Negative and False Negatives, like visible above. If you’d repeat the same identical test changing the Detector with another with superior characteristics, you’d also see that the same Sensitivity threshold adjustment of the former test is now allowing a huge cut on Production losses, the False Positives (FP, pink colour). The fraction of actually-labelled bottles falsely considered nonlabelled. Production losses’ reduction without any increase of the False Negatives (FN, light blue colour), say the actually-nonlabelled bottles erroneously considered labelled and not rejected (abridged by Jutta234 (http://commons.wikimedia.org/wiki/User:JuTa)/CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)/2006)

In brief, ROC analysis is relevant in all our applications because allows:

- to graph the Sensitivity of our Detector, in this case, a digital photoscanner used to detect the presence of a label, as a function of the False Positives. False Positives that in our Food and Beverage Bottling industrial field are commonly (and, unproperly) named *False Rejects;*
- a precise evaluation of the fraction of actually-nonlabelled bottles (True Negatives, TN) as a function of the fraction of actually-labelled bottles falsely considered nonlabelled (False Positives, FP).

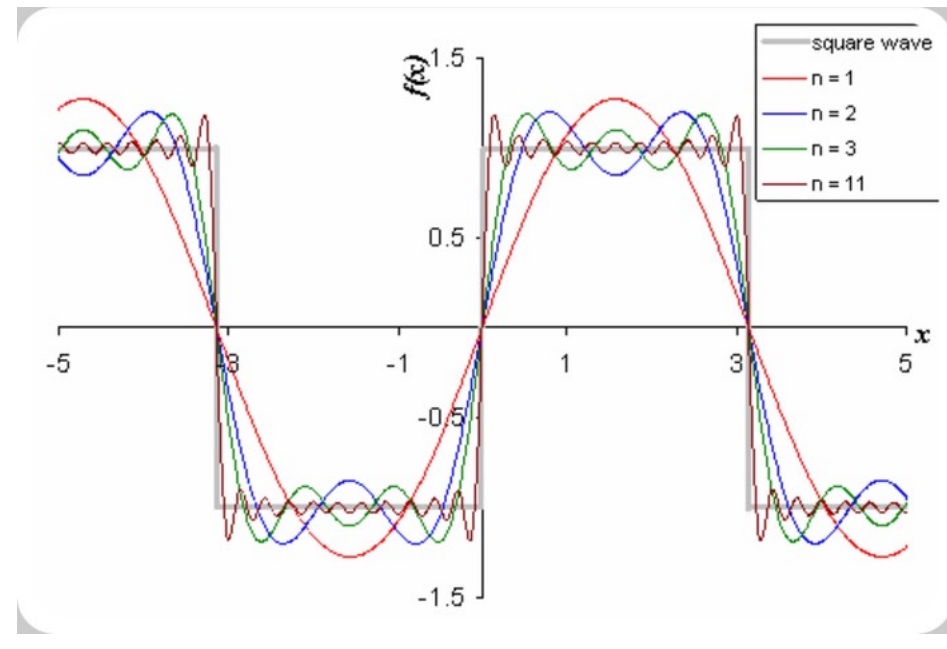
“ROC analysis allows a precise evaluation of the fraction of actually-nonlabelled bottles as a function of the fraction of actually-labelled bottles falsely considered nonlabelled”

[redacted]

Fourier, Signal-to-Noise ratio and Rejects

The choice of the *photoscanner*, also named *photo-electric sensor* or *photo-detector*, occupies a central role. It has not to contradict what the Experts of Radio Frequencies' technologies perfectly know. Namely, that the conversion between the electromagnetic form of the energy and the electric is made in the *"antenna"* and that's why this is the component where to invest a sensible part of the entire value of a detection system. Why ? Also, but not only, because otherwise the distortions introduced by the transducer of the electromagnetic ⇒ electric Signal, first link of the detection-amplification-switching chain, shall have further amplification. Amplified jointly with the truly incoming Signals (see figure below at right side), until an output signal of high amplitude no more resembling the truly incoming Signal. There is a name, the name of the great French physicist and mathematician Jean-Baptiste Joseph Fourier whose discovery since two centuries dominates the entire Mathematical-Physics and its Engineering applications.

Whatever periodic function however complex, may always be represented as the superposition of an average constant value and two periodic series, in cosines and sines, including infinite terms. As an example, subtracting by the superposition all the odd-numbered terms and leaving only the even-numbered and the average value, a sinusoidal function becomes a squared-function. A Detector subtracting and/or adding and/or modifying the amplitudes of each one Fourier's term, is introducing a *distortion*. Aperiodic signals are treated pretending that they are periodic with an infinite period



It makes sense of the components:

- existing in the Output Signal, but non-existing in the incoming Input Signal,
- plus others, nonexisting in the Output Signal, but existing in the Input Signal.

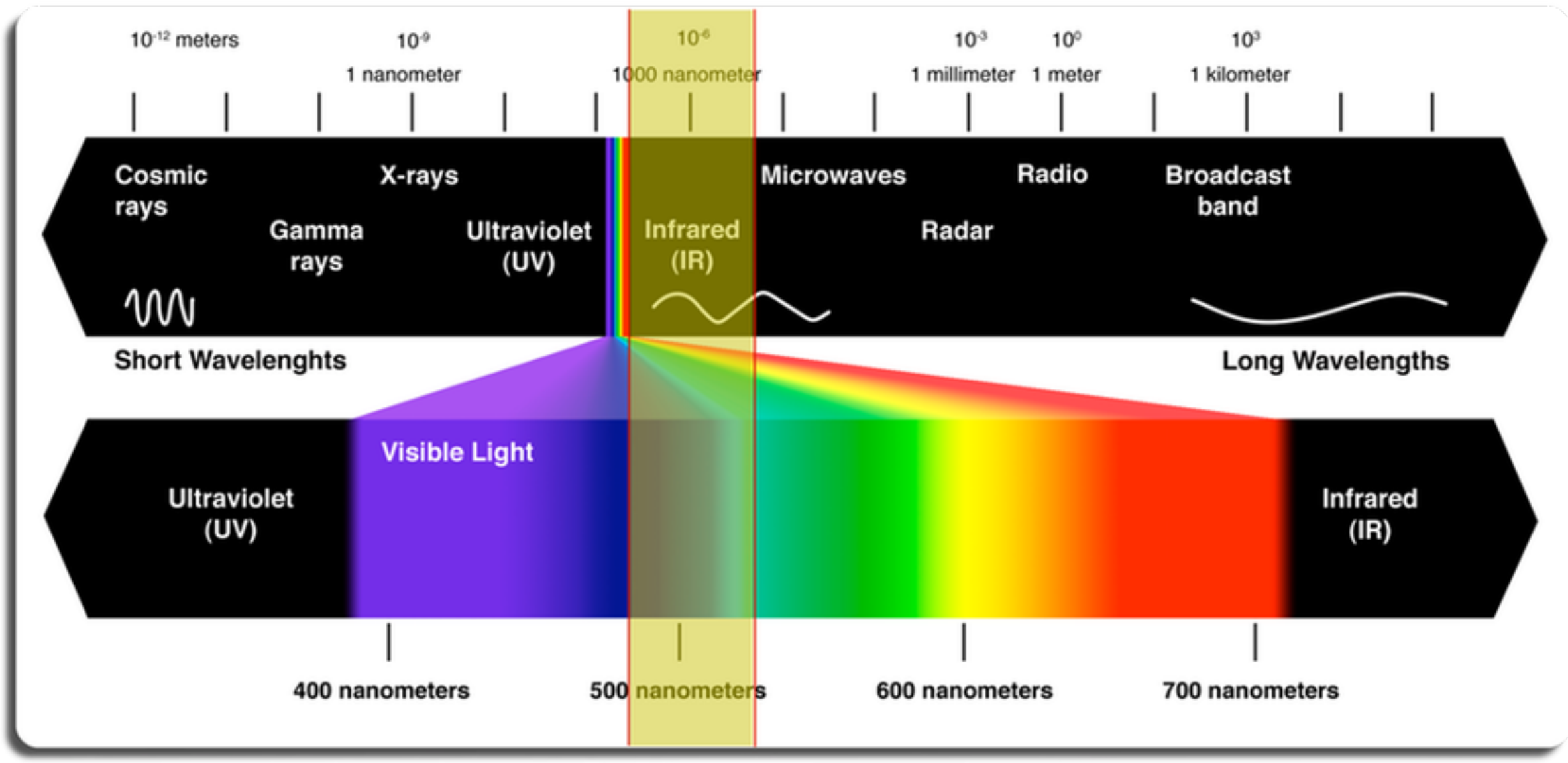
A digital photoscanner in a Label Presence Inspector may be imagined alike an electronic component acting similarly to an antenna, but with a basic difference in its output signal. Output signal which is not analog like those of the aerials, rather a digital on-off corresponding to:

- normally open (NO) and/or normally closed (NC) contact,
- and/or PNP and/or NPN polarity.

Two of the specifications are particularly relevant during Label Presence Inspection:

1. centre of the waveband of the Photoscanner light emission;
2. detection diagrams, showing the response curve.

For the point 1. above, refer to the electromagnetic spectrum visible in the figure below, where it is visible a waveband centered in the infrared (IR). In the following, we'll focus some of their characteristics.



The portion of the electromagnetic spectrum named Infrared (IR)

Photoscanners' Margin feature

The data sheet visible below is not that of the general-purpose designed ~40 years ago and present wordwide in many electronic inspectors. Rather another general-purpose, modern and high-Quality photoscanner. One of the most fundamental technical features of the photoscanners or photodetectors is named *Margin.*

"Margin" is defined as the measurement of the amount of light from the light source detected by the receiver, expressed as a multiple of the minimum amount of light level required to switch the sensor output.

"All sensors should be operated at a margin greater than 2x (x, the minimum amount of light necessary to switch).

Detection of a low reflectivity target notoriously requires sensors with higher margin: higher Quality sensors"

Then, a margin of 2x is reached when the light level received is twice the minimum required to switch the output.

All sensors should be operated at a margin greater than 2x. Detection of a low reflectivity target notoriously requires sensors with higher margin: higher Quality sensors.

As an example, refer to the Data Sheet for the Photoscanner at right side.

Visibly:

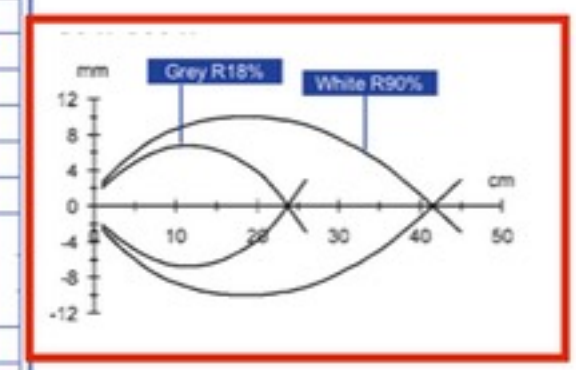
1. *light emission is Infrared, centered at a wavelength of 880 nm (IR)*;
2. *detection diagram hints to another property (label colour and reflectivity)*. Showing, as an example, that a grey colour (flat) surface at 10 cm of distance provides the top of the detected signal. A distance which is doubled to 20 cm if the surface is white colour, then more reflective;
3. *detection diagrams are always and only referred to a flat surface* an
 d not to a curved one, like a label applied to a bottle. Implying that the amount of
 iffused reflected electromagnetic energy is much superior to that available in our beverage packaging inspection. Implying, as an example, that a grey coloured label has to be optimally detected at a distance shorter than 10 cm and a white label, at a distance shorter than 20 cm.

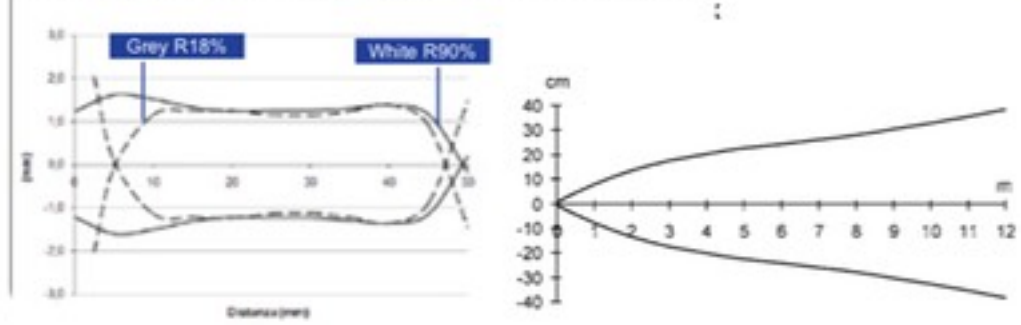
TECHNICAL DATA

Power supply:	10 ... 30 VDC (D.C. VERS.), REVERSE POLARITY PROTECTION
	15 ... 264 Vac (a.c. vers.)
Consumption:	30 mA max. (d.c. vers.)
	10 mA max. (a.c. vers.)
Light emission:	infrared LED 880 nm
	red LED 660 nm (B, E1 vers.)
Diffuse proximity operating distance:	1 ... 10 cm (C10 vers.), 1 ... 8 cm (C8 vers.)
	1 ... 35 cm (C35 vers.), 1 ... 30 cm (C30 vers.)
	1 ... 60 cm (C60 vers.)
Fixed focus operating distance:	15 mm with 1 mm spot (D15 vers.)
	50 mm with 2 mm spot (D50 vers.)
Retroreflex operating distance:	0.1 ... 4 m (on R2)
Polarised retroreflex operating distance:	0.1 ... 3 m (on R2)
Retroreflex for transparents op. distance:	0.1 ... 0.8 m (on R2)
Through beam operating distance:	0 ... 12 m (F/G12 vers.), 0 ... 8 cm (F/G8 vers.)
Setting:	sensitivity trimmer
	(A4, C8, C10, D15, D50, G vers. excluded)
Indicators:	red OUTPUT LED
	green STABILITY LED (d.c. vers.)
	red POWER LED (G vers.)
Output type:	NPN or PNP configurable (d.c. vers.)
	SCR + bridge rectifier (a.c. vers.)
Saturation voltage:	2.5 V max. (vers. d.c.)
Output current:	150 mA max.(vers. d.c.), short-circuit prot.
	100 mA max.(vers. a.c.)
Response time:	500 µs (D50 vers.)
	1 ms max.
	2 ms (F vers. in d.c.)
	20 ms max. (a.c. vers.)
Switching frequency:	1KHz (D50 vers.)
	500 Hz max.
	250 Hz max. (F vers. in d.c.)
	25 Hz max. (a.c. vers.)
Operating mode:	dark/light (configurable in 4 wires d.c. vers.)
Auxiliary functions:	'test +' and 'test -' inputs (G vers. in d.c.)
Connection:	4-pole M12 connector or 2 m Ø 5 mm cable
Electrical protection:	class 1 (a.c. vers.); class 2 (d.c. vers.)
Mechanical protection:	IP67
Housing material:	ABS
Lens material:	PMMA plastic
Weight:	25 g max. (connector vers.); 100 g max. (cable vers.)
Operating temperature:	-25 ... +55°C
Storage temperature:	-25 ... +70°C
Reference standard:	EN 60947-5-2
Certifications:	(CE vers.d.c.)

The operating distances indicate the detection distance with excess gain 2.

DETECTION DIAGRAMS





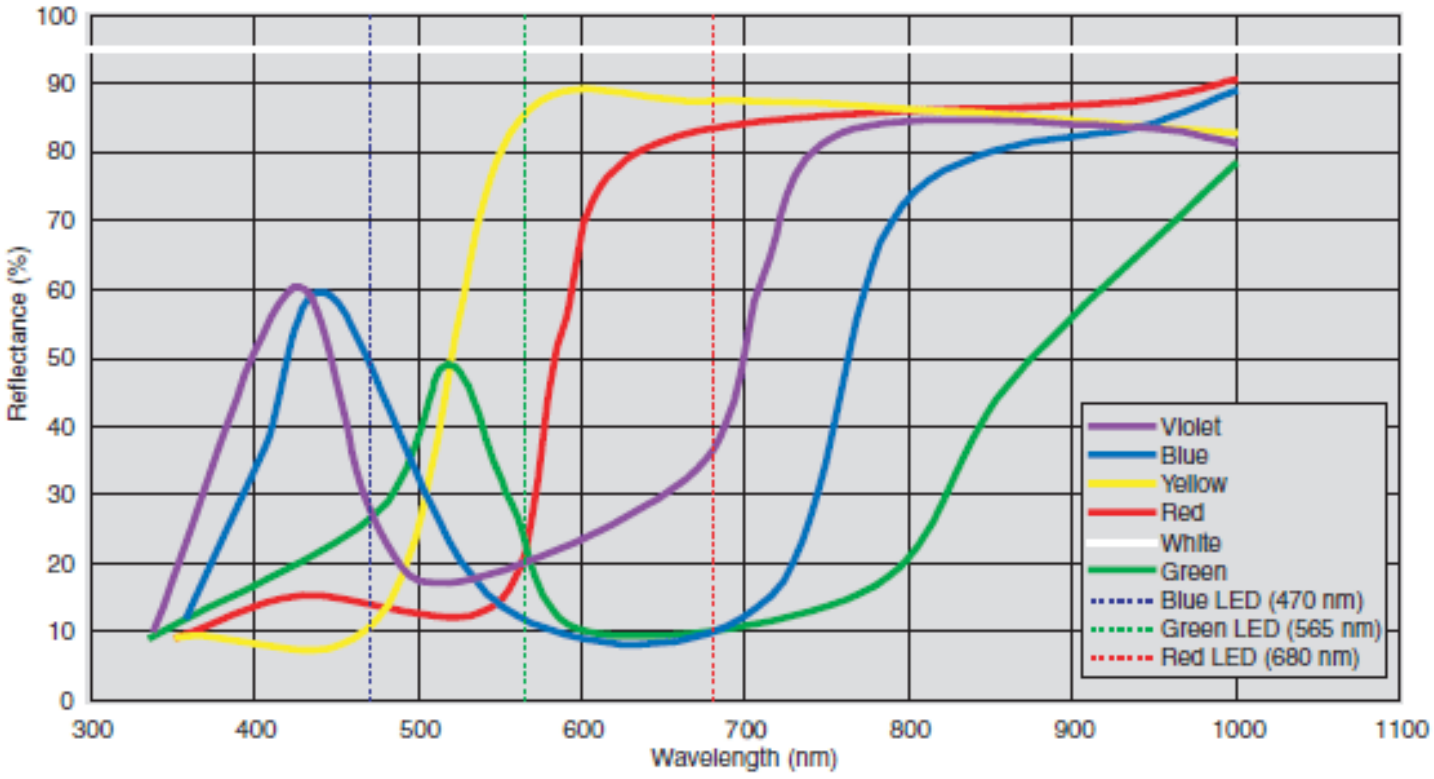
The detection diagrams indicate the typical operating distanc
with excess gain 1.

Focus on the packaging

If the labels whose presence has to be detected are:

- *dark,* and not clear colour, then less reflective, like visible in the figure below,
- *curved*, and not flat, then reducing the amount of electromagnetic energy retro-reflected into the phototransistor of the Photoscanner, the semiconductor device whose output signal is typically the input of a transistor acting as amplifier,

the photoscanner shall not be adapt to fulfil the Technical Guarantees for the entire Label Presence Inspector.



Maximum reflectance of flat labels of various colours, as a function of incident light's wavelength (📷 Omron Corporation/2006)

If this is the case, meaning that following the kind of commissioning the photoscanner received, the Electronic Inspector shall unavoidably show:

- False Positives, say correctly labelled bottles uncorrectly detected non-labelled and then rejected,

or:

- False Negatives, say truly non labelled bottles, not detected and not rejected,

and, sometimes:

- False Positives mixed with False Negatives.

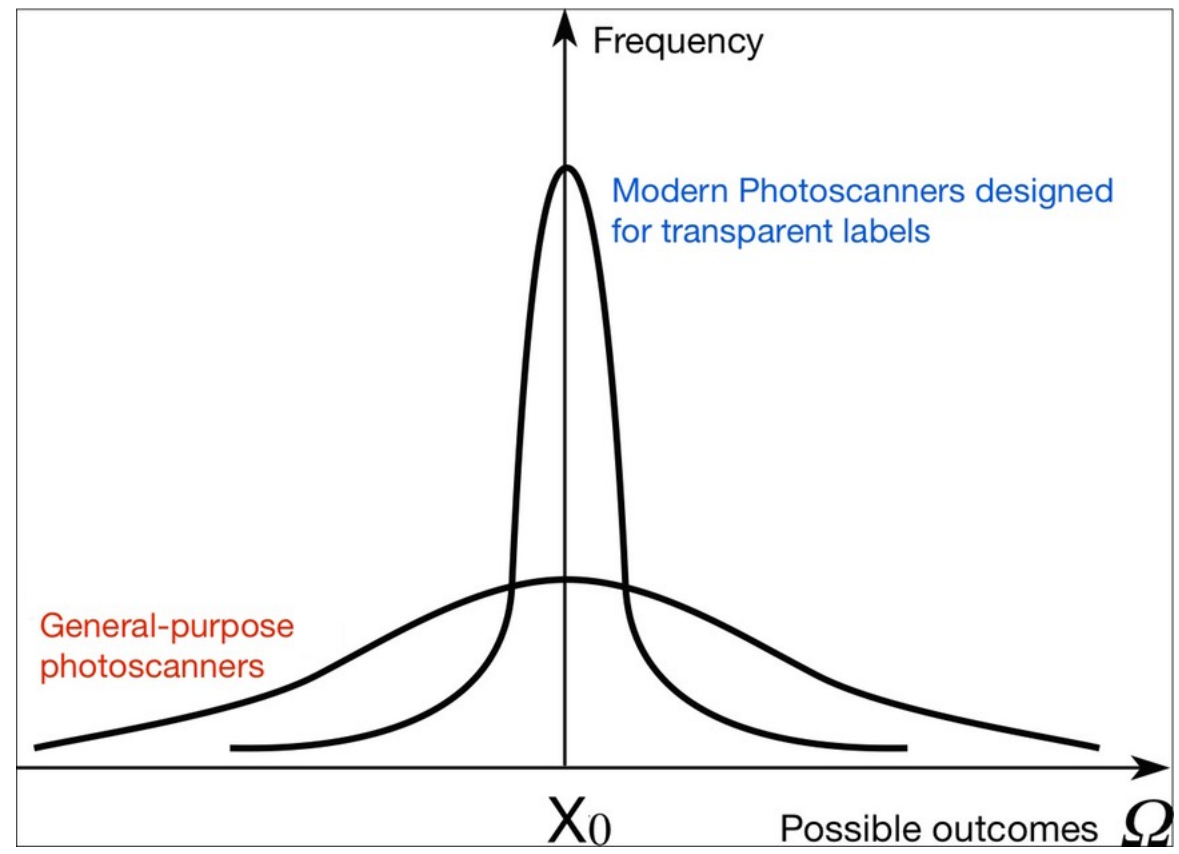
"Detection of a low reflectivity target notoriously requires sensors with higher margin:

higher Quality sensors"



Assessing the quality of labelled bottles in a SAB MIller Brewery. In the distance, the rejects of the Full Bottle Inspector controlling Label Presence *in-the-Labeller* and Fill Level *at-the-Conveyor* at left side (Kompania Piwowarska SA/Tom Parker/OneRedEye/2012)

We'll deepen in the following section the main reason for so many Production losses frequently observed as a result of the Label Presence Inspection. What follows cannot be generalised to all Vendors. But, it touches however directly ~70 % of all the Label Presence Inspectors presently operating in the entire World. The Label Presence inspection most important component is its *digital photoscanner,* also named diffuse reflective sensor, photo-detector, photoelectric sensor, etc. Too frequently, also the component where are concentrated the efforts of some Designers to contain the grand total cost of all the Electronic Inspector's parts. Not many Designers but, being one of these Vendors market share as high as 40 %, the net result that the sum of all these Label Inspectors accounts in the end for ~70 %. As an example, refer to many Label Presence Inspectors sold to Food and Beverage Packaging Companies whose price lies in the range (30000 ÷ 120000) $, or (25000 ÷ 100000) €. You'll discover what only Experts know, that the most important component of a Label Inspector is reduced to a *"general-purpose photoscanner born by a design of ~40 years ago"*.



Cheap, obsolete general-purpose photoscanner versus modern, expensive photoscanner designed for transparent labels. What happens when exposing a statistically significant number of times one and the same labelled bottle to two different technologies' photoscanners

If you want to remain astonished and go closer to the reality of the facts, try to Google the words:

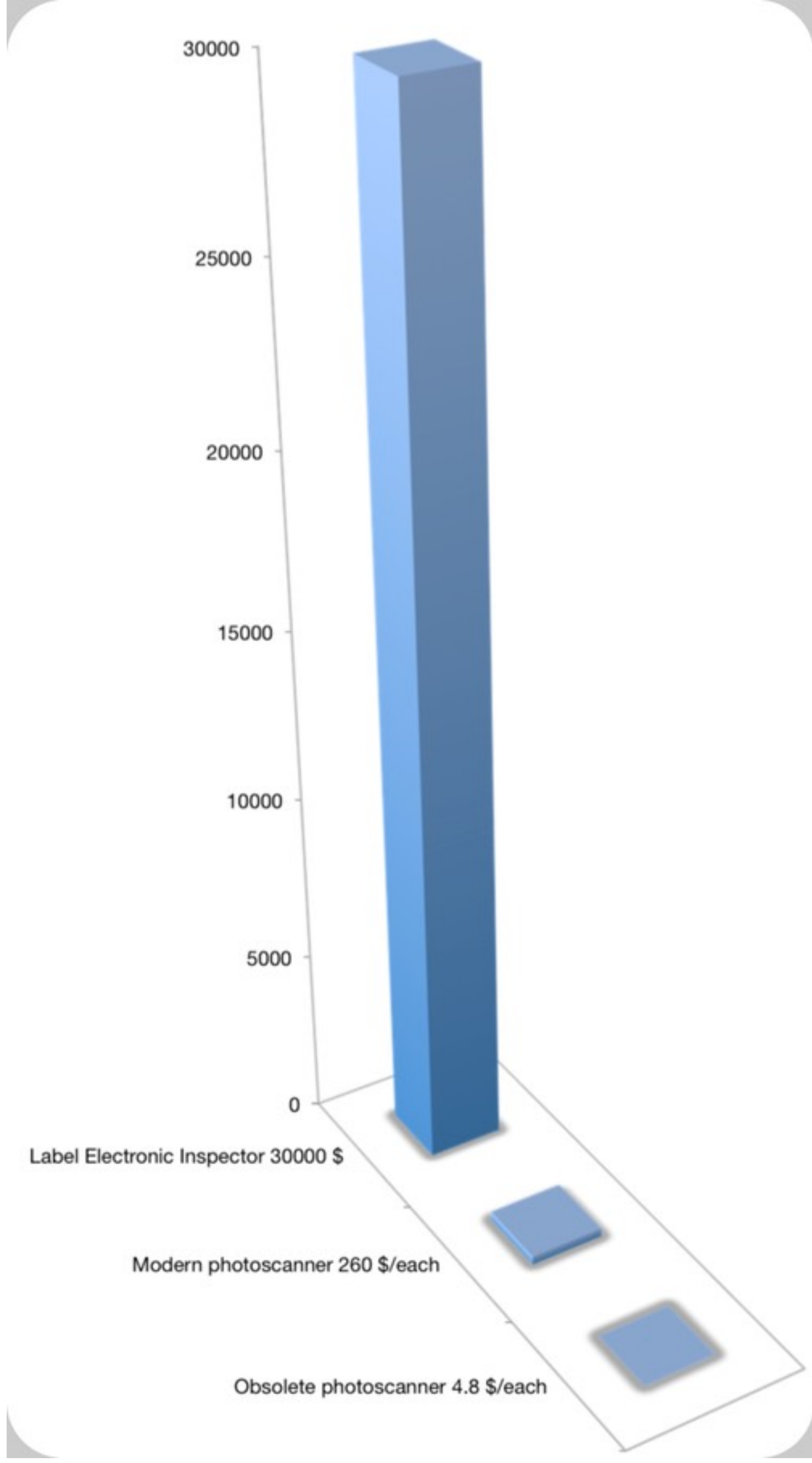
18mm-Diffuse-Type-Adjustable-Photoelectric-Sensor-Switch

and, in the lot of the results you'll encounter that these transducers, the core of the Label Inspection, are components which, if bought in amounts of >100 units, are paid just 4.8 $, or ~4 €.

To have a first contact with the key point, imagine to have just one bottle:

1. labelled with a Neck Label of the today commonly adopted semi-transparent kind;
2. let it revolve on a rotary carousel on a plate and its retro-reflected diffuse light be detected by two photoscanners differing in their basic characteristics and prices;
 One of them a cheap (4.8 $/each) general-purpose the other an expensive modern model specifically designed for semi-transparent, transparent or dark labels;
3. write down each outcome in the sample space Ω of the A/D converted measurements derived by the Label Presence Inspection. Outcomes of measurements displayed by the Label Presence Inspections of different Vendors and technologies, as: adimensional numbers, or distances in millimetres, or pulses, etc.;
4. translate the obtained gaussian profiles, til superimposing their respective averages;
5. observe the spiked distribution of the modern photoscanner (260 $), explicitly hinting to high repeatability and low false rejects to be expected in Production;
6. on the opposite, the cheap general-purpose photoscanner, costs 68 times less than the other, but reduces the entire Beverage Bottling Line Production losses and non-labelled bottles to the Market, along the following 15 years;
7. evaluate the cost of an individual False Positive (false reject);
8. evaluate the relative contribution to the Total Cost of Operation (TCO) of the less performant technology Neck Label Presence Inspection, using the other as a reference, integrating it along the expected 15 years of lifetime of that Electronic Inspector;

9. you'll discover that the general-purpose photoscanner, applied in a Labeller to the detection of the modern semi-transparent, transparent or dark labels, shall cost you losses much superior to the price of a second Electronic Inspector ! Much, much more than the price you'd have paid (260 $) to eliminate this problem banally upgrading the photo-Detector technology to the Third Millennium's Designs.



Cheap, obsolete general-purpose photoscanner versus modern, expensive photoscanner designed for transparent labels. Shown their pricing with respect to a Label Presence Inspector priced 30000 $ (25000 €). The False Rejects you suffered until today, have a well-defined definite Root Cause. The cheap obsolete photoscanner commonly fabric-installed, literally disappears in the comparison. Weighing just 0.12 ‰ of the Label Inspector price. Disappears in the comparison but not in the negative accountancy of a Beverage Bottling Line Production's Losses

A few calcultions tell us that these Design choices are presently devoting to the most important Label Presence Inspection component, just a nearly infinitesimal fraction. Considering Label Electronic Inspectors valued 30000 $ and 120000 $, just:

$$(0.16 \div 0.04)\ ‰$$

thus, affecting negatively the Receiver Operating Characteristic (ROC) exactly in the most critical, prone-to-falsely-reject Label Presence Inspections. Above, graphed the comparative relative porcentages of a relatively cheap Electronic Inspector (30000 $), and of two kinds of photoscanners it may use as transducers for its Label Presence Inspections. The modern relatively expensive model, designed for the actual and difficult transparent and semi-transparent labels, costs <260 $. It is the "expensive" solution. The cheap obsolete photoscanner commonly fabric-installed, literally disappears in the comparison. Weighing just <0.16 ‰ in the total Label Inspector price. Disappears in the comparison but not in the negative accountancy of a Beverage Bottling Line Production's Losses.

The red colour boxes evidentiate mainly transparent self-adhesive labels. Its reflective area reduced to just small texts, thus requiring photoscanners' orientation at the text. As a consequence, it'll result impossible to detect flagging or inclined labels. Detection reduced to the mere label presence or absence. A typical case benefitted by the modern photoscanners including microprocessors, processing with fuzzy-logic just polarised light. Detectors conceived for these kinds of labels



All general-purpose cheap photoscanners, widespread and costing a few dollars, adopt circularly polarised light as interactant. Circularly polarised is just a way to say that no filtering exists for a specific polarisation angle: all of them are used. Now, imagine to superimpose to the clear reflective foam in these necks a relatively dark Neck Label. Marketing Dept., and not the Bottling Dept., decides colours and shapes on base of reasons which are nearly completely out of those where the Beverage Bottling Staff may prevent a new format of label definetely so "dark". Labels less reflective than the foam, implying foam emulating non-existing labels. Add a low-reflective dark label, applied in the most curved area of the bottle, to a relatively fast Labeller Machine (>40000 bph), let them checked by an intrinsically low-Quality Photoscanner of the Electronic Inspector. The grand total shall be a maximum of Production Losses and minimum Quality. What to do in these unfortunate cases ? Impossible to change labels then upgrade the photo-Detectors

(SABMiller, Kompania Piwowarska SA, Poland /Tom Parker/OneRedEye/2012)



General-purpose photoscanners' scope

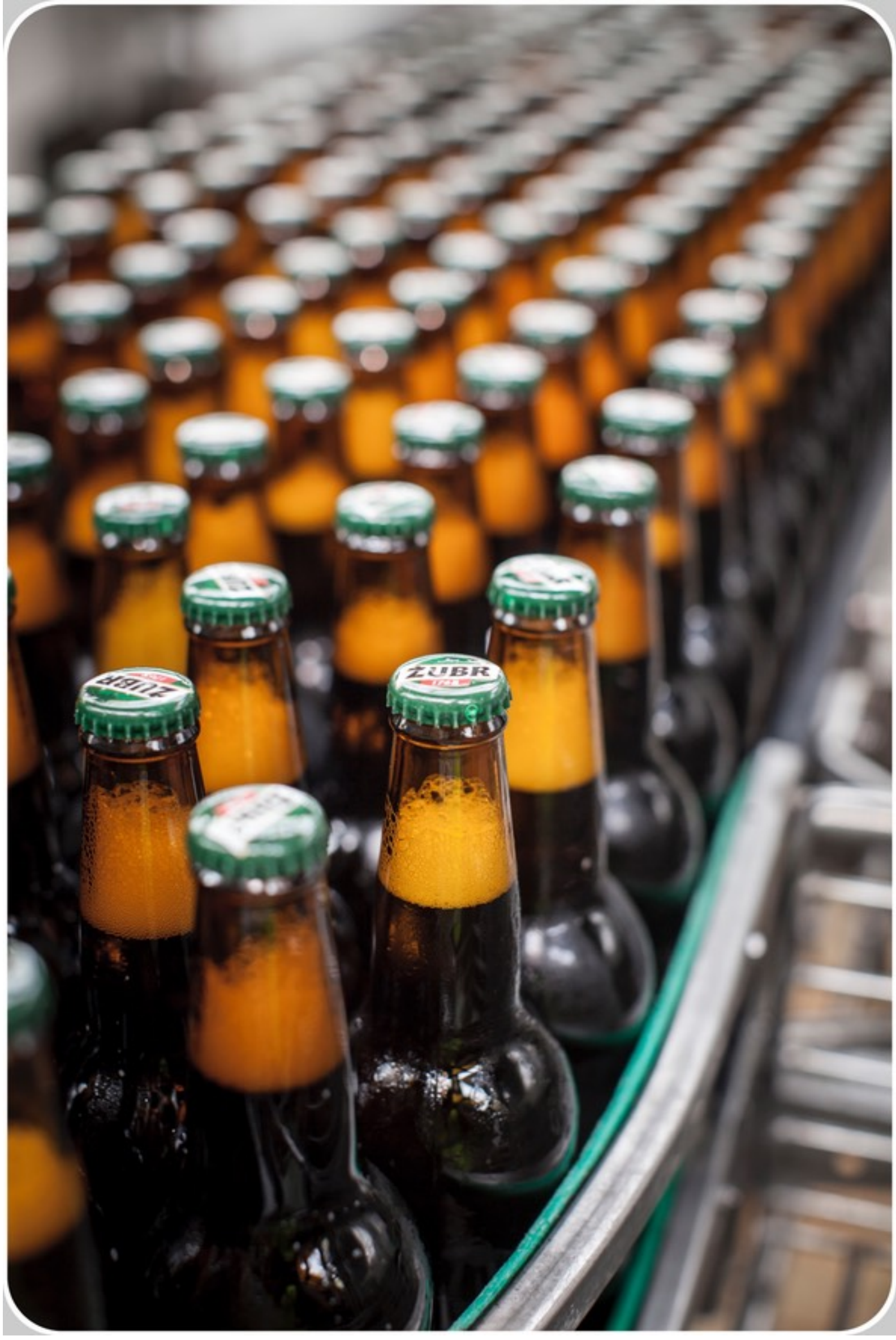
Finally, we think you could be interested to know to what kinds of labels the cheap photoscanners are adapt. It's a long history started well before Electro-Optic components started to be applied in the Food and Beverage Industry. In 1931 Paul Kubelka and Franz Munk created a relevant part of the *Theory of Reflectance.* They developed it with paint films in mind and discovered that it also worked quite well in many circumstances also for paper. The Theory works best for optically thick materials, those where >50 % of light is reflected and <20 % is transmitted.

Comprehensibly, the modern semi-transparent, transparent and very dark labels are exactly those where <50 % of the light is reflected and >20 % transmitted or absorbed.

These two German scientists, however, saw their Theory was not completely rendering the diffused reflection of the:

- dyed papers,
- very dark, unbleached papers,

when light absorption reaches a high level.


ZUBR
ZUBR



And one more constrain of their Theory is that the absorbing and scattering media have to be uniformly distributed through the label.

The Theory was not created for the kinds of labels we name “critical”:

- very dark and absorbing, nearly never used in 1931, during an epoch of human visual Label Presence inspection,
- plastic transparent self-adhesive labels today so common.

When the general-purpose photoscanners, today priced 4.8 $/each were conceived, over 40 years ago at the start of the Electro Optics industrial applications like the LEDs, Kubelka-Munk's *Theory of Reflectance* was correctly representing also all then existing paper labels. Poliethilene and PVC transparent or semi-transparent self-adhesive labels, today so common and probably tomorrow the only kind to be used, started to enter the Beverage Bottling and Labelling decades later.

Label inspection with Polarised light

When they were developed, around 40 years ago, what are today considered by too many Vendors as “standard” photo-electric sensors to be devoted to label presence inspection, polarised light was yet a standard. But a standard for Military and Scientific applications, and not in the Civil industrial applications like those of the Food and Beverage Industry. Why polarised light ? The answer lies in the solution of a key problem. One affecting all imaging, included the human visual imaging, is that most sources of light are classified as incoherent and unpolarized (or only “partially polarized”) because they consist of a random mixture of waves having different spatial

characteristics, frequencies, phases, and polarization states. These superimpose themselves in the photo-detectors and the effect are phenomena of destructive interference. As an example, imagine to illuminate a photo-detector with 1 joule of radiant energy, later discovering that the Signal shall be later represented by only a small fraction of a non-negligible amount of energy which entered the detector.



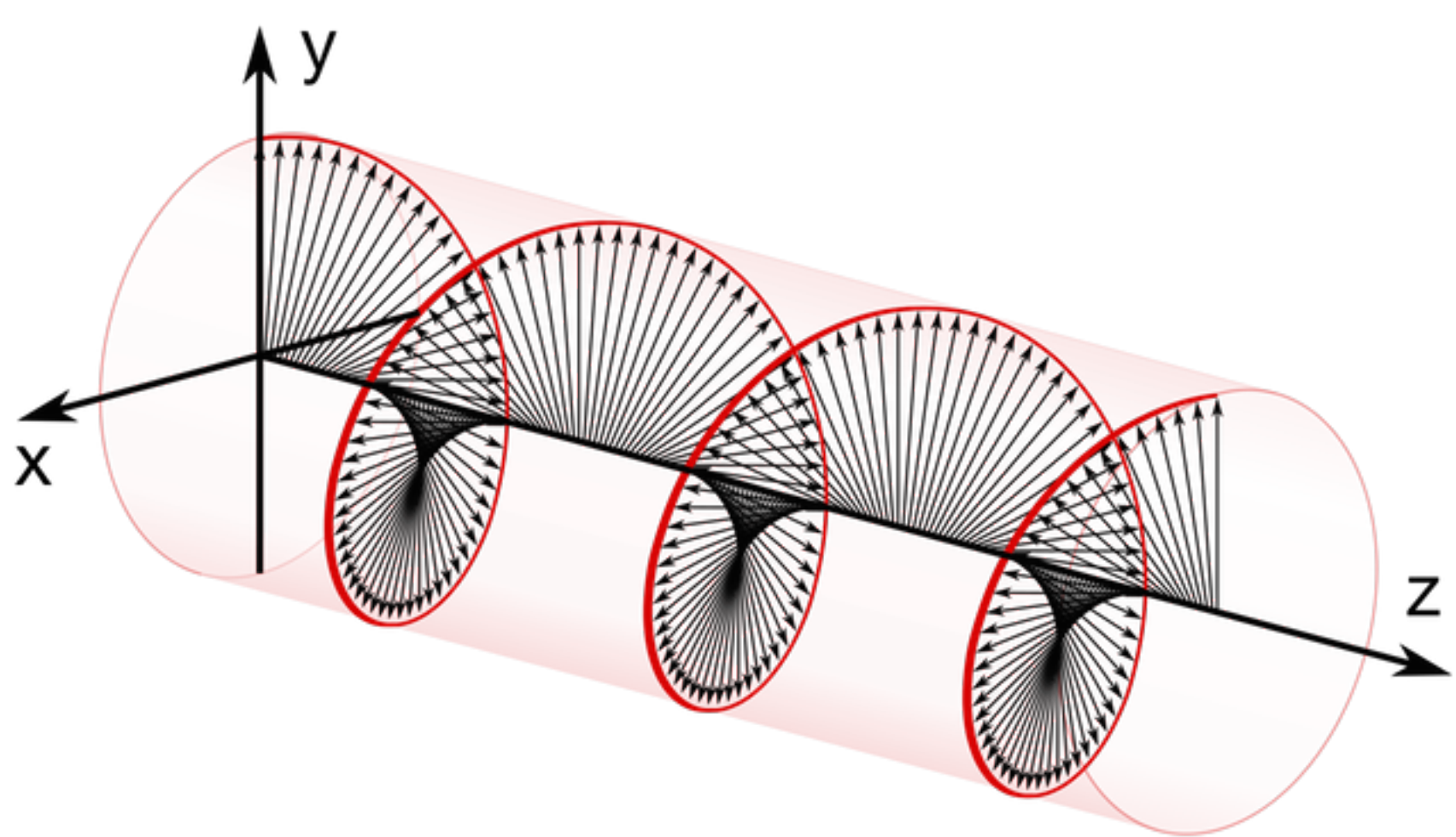
Label Presence Inspection without (left) and with (right) photoscanners adopting polarised light. At right side, the adoption of polarised light shows the impressive increase on the Signal-to-Noise relation for a common transparent self-adhesive plastic tape

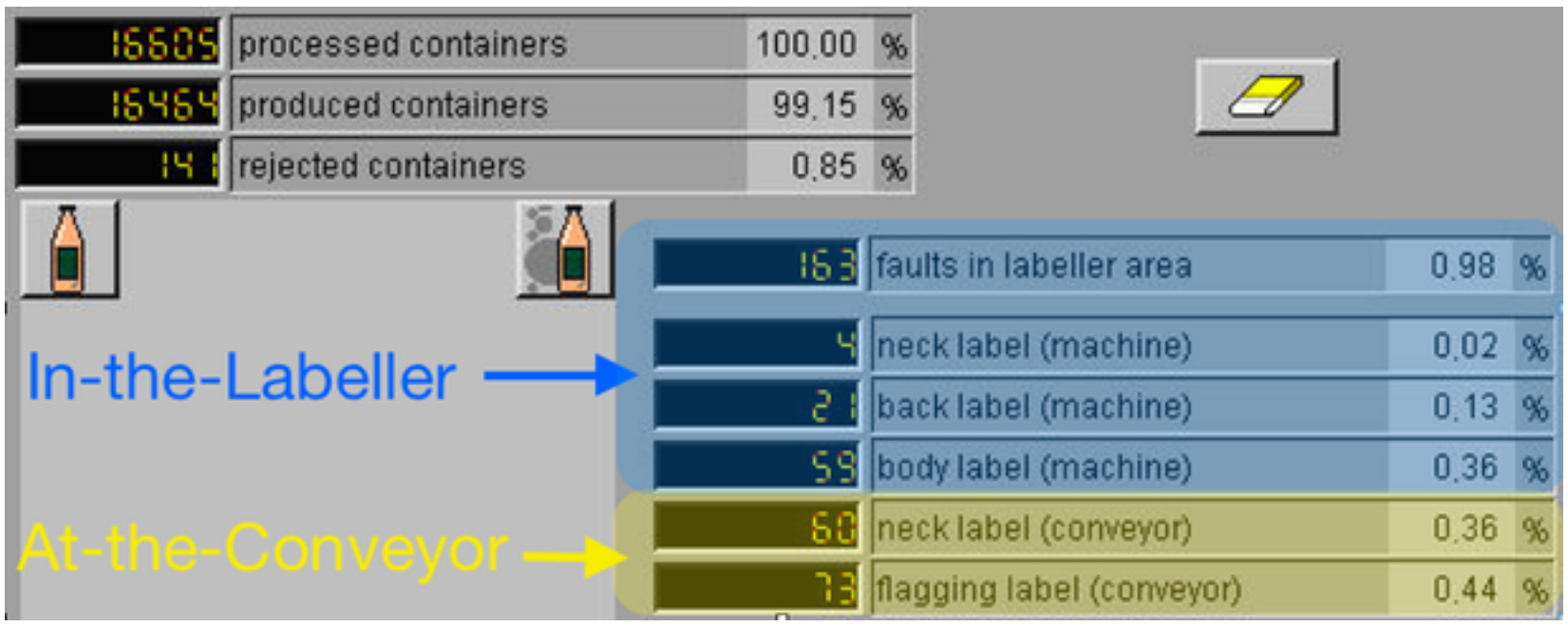
Above a common plastic self-adhesive tape as seen by one and the same optic:

- **left side**: what a 4.8 $ “standard” photoscanner detects. Its LED illuminates the label with circularly (360º) polarised light. Also the reflected diffused light is not polarised. The effect is that the plastic tape nearly disappears yet when over 1 million of pixels are used to detect it.
- **right side**: what a 260 $ modern high-Quality photoscanner detects. Its LED illuminates the label with light polarised in just one specific angle. Also the reflected diffused light reaches the phototransistor after passing through a polariser filter oriented the same angle as the LED emitted light. The effect is that the plastic tape is distinctly visible. In the meantime, the light blue background, equivalent to Noise in whatever Signal-to-Noise relation ratio, disappears. A further contribution to the immediate and cheap reduction of the false rejects of whatever Label Inspector.

The impressive increase of the Signal-to-Noise ratio felt when circularly polarised light is emitted through a polariser filter and later detected again filtered by a second polariser, depends by a non-classic quantum feature of the photon named “spin”. In the example depicted here, shown left-handed clockwise circularly polarised light propagating along the z-axis. Integrating several of these waves in a photo-detector let them interfere destructively. Meaning less photons detected with the same spin angle, each one of them contributing to form the *Signal*

Flagging-labels





Label inspection counters for an electronic inspector with inspections in-the-Labeller and redundants at-the-Conveyor

An electronic inspector with photoscanners *in-the-Labeller* Machine may be usefully equipped with additional label inspections in the Conveyor, preventing flagging labels from reaching the Market. More, Labeller's brushes may remove labels yet applied and detected applied by the photosensors. Thus, to have a final check out of the Labeller *at-the-Conveyor*, results cheap and advantageous.

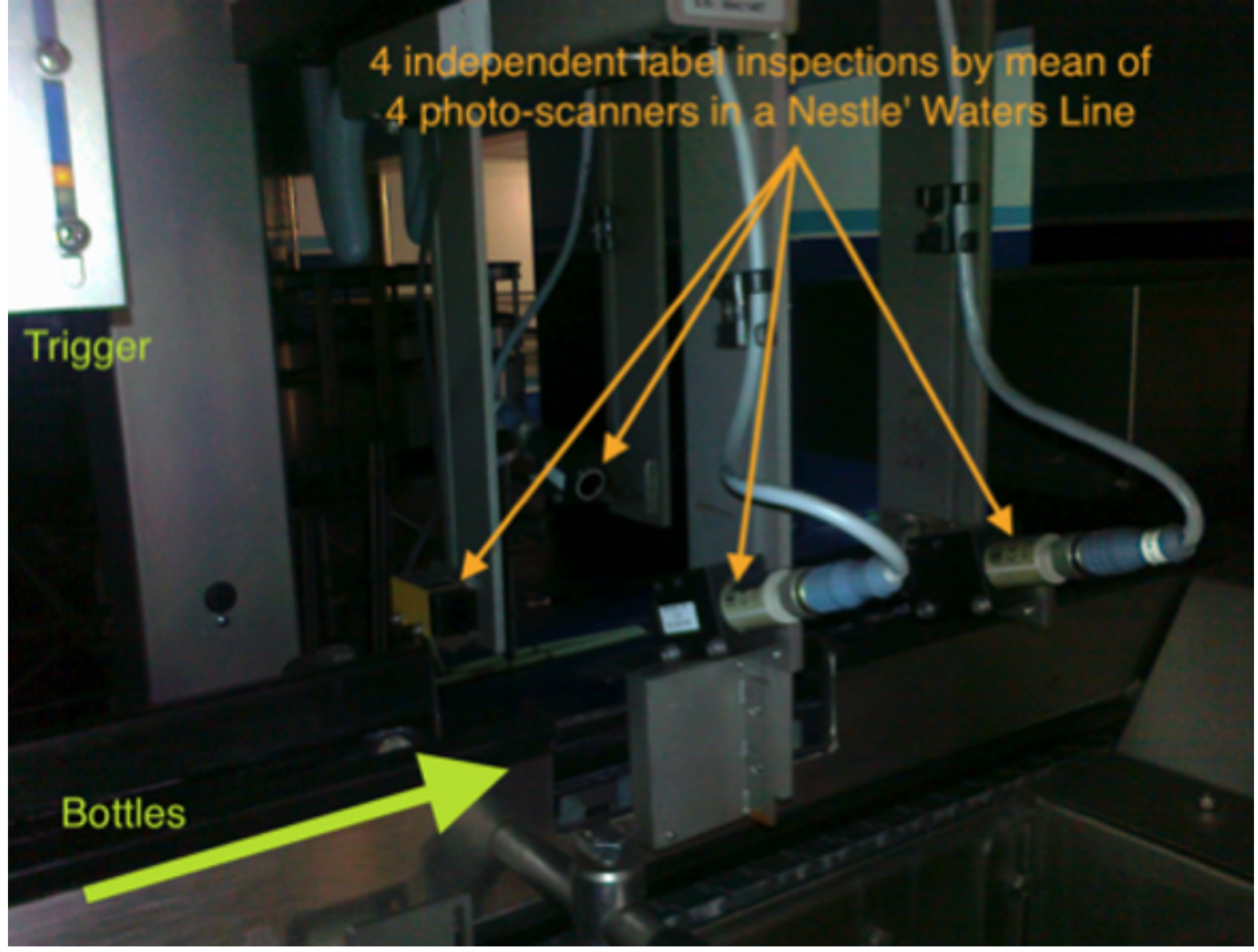
A different, extremely cheaper approach in the figure below. Here, four additional independent label inspections check the wrap-around label position by four different places. Photoscanners' independence being the key to satisfactory performances, without extra-costs, operative complexity and expensive spare parts, always associated to camera-systems.

Flagging label inspection, by mean of four independent inspections, adopting the cheapest general-purpose photo-scanners. Their outfeeds take advantage of the Probability Multiplication Theorem. Application on PET bottles labelled with semi-transparent labels

Such a design profits of the implications of the Probability Multiplication theorem. Applied to an Electronic Inspector (a Binary Classifier) composed by:

- a set of N inspections, identified by the suffix-i, each one having:
 $0 < \textit{detection ratio} < 1$;
- whose individual rejects converge to a single Rejector;

the probability that each one of the N inspections fails to detect a single defect is reduced to:



$$\prod_{i=1}^{N} \textit{Inspection detection ratio}_i$$

Now, imagine to have a first inspection *in-the-Labeller Machine,* and four redundant successive of that same label *at-the-Conveyor.*

The probability $P_{1,2,3,4,5}$ of joint occurrence of five events *1, 2, 3, 4, 5,* any collection of outcomes of an experiment:

- whose respective probabilities are P_1, P_2, P_3, P_4 and P_5;
- $0 < P_i < 1$;
- following normal (gaussian) distribution;
- reciprocally independent;

is the product of their individual probabilities:

$$P_{1,\,2,\,3,\,4,\,5} = P_1 * P_2 * P_3 * P_4 * P_5$$

Finally, after considering that each one of the N inspections has:

$$0 < \textit{detection ratio} < 1$$

it results immediately evident an impressive reduction on the amount of defective containers falsely considered “correct” (False Negatives), proceeding to the Market.

Case Study

5 Binary Classifiers in a single Label Presence Inspector

As an example, we’ll consider the case with N = 5 (five) inspections, all of them featuring the same individual False Positive (false reject) ratio FPi < 0.01 %.

Five independent Binary Classifiers, independently acting on a single rejector, whose individual:

- accuracies;
- reproducibilities;
- specificities;
- sensitivities;

are such that the same property of an object is classified with Probability of False Negatives, say the undetected nor rejected but truly “defective” bottles:

10.00 %

Defects’ Detection Ratio

The joint probability representing the Risk R that the five homogeneous systems (inspecting different projections of the same physical property, in different *sample spaces* of one and the same *state space*) simultaneously fail to recognise one and the same defect, shall be limited to:

$$R_{1,\,2,\,3,\,4,\,5} = \prod_{i=1} R_i = 0.001\ \%$$

Meaning:

- that no more than 1 (one) non-labelled bottle in a row of 100000 non-labelled consecutive bottles out feeding by the Labeller Machine, shall not be detected defective by the Electronic Inspector, thus passing to the Market,
- detection ratio >99.998 %.

False Rejects Ratio

We can look also on the other side, to the expected average value of the False Positives (false rejects) deriving by the superposition of the random variables measured by a Binary Classifier. We have immediately different possible approaches, corresponding to

our own prudential choice. In this context, the term *"prudential"* is related to the level of confidence we attribute to the classification enacted by each individual Binary Classifiers.

For the value expected by the sum (or, superposition) of N independent random variables, following the confidence we attribute to the outcomes of our measurements, we'll have at least three kinds of estimation:

1. *most prudential*
2. *prudential*
3. *less prudential.*

1. Imagine that we'd decide to adopt the *most prudential definition of sum* of N independent random variables, an Electronic Inspector (a Binary Classifier) composed by a set of N inspections whose individual rejects R_i converge to a single Rejector (or, ejector), each one identified by the suffix-i. In this case, the probability that each one of the N homogeneous inspections simultaneously and erroneously classify "defective" (False Positive) their physical measurements of a container has an upper bound which is their sum:

$$\sum_{i=1}^{N} Inspection\ reject_i$$

and, for i = 1, 2, …, 5 we'll have:

$$FP_{expected\ \%} < 0.05\ \%$$

2. Adopting the *prudential definition* of superposition of N independent random variables, we'll have a correspondingly ***best estimation of the expectation value*** for the total False Positives (false rejects) of the entire system of Binary Classifiers, as:

$$\sqrt{\sum_{i=1}^{N} Inspection\ reject_i^2}$$

which let us estimate the Total False Positives ratio as:

$$FP_{expected\ \%} = 0.022\ \%$$

3. Adopting the *less prudential definition* of superposition of N independent random variables, we'll have a correspondingly *estimation of the expectation value* for the total False Positives (false rejects) of the entire system of Binary Classifiers, as:

$$\frac{1}{N}\sum_{i=1}^{N} Inspection\ reject_i$$

implying an estimation of the Total False Positives ratio:

$$FP_{expected\ \%} = 0.01\ \%$$

Conclusions

Well before to mislabel 100 000 consecutive bottles, the Rejects Accumulation Table of the Electronic Inspector, should be fully occupied by rejects. The sensor of the Conveyor Control Cabinet managing this part of the Beverage Bottling Line, set in the Rejects Accumulation Table should control an automatic stop of the Labeller Machine.

The straightforward application of the frequentist definition of Probability, silently assuming an infinite capability to accumulate rejected bottles, is countered by a reality where the:

1. limited accumulation space, typically (80 - 300) standstill bottles, on the Rejects' Accumulation Table,
2. existence of a sensor to detect that status and controlling Labeller Machine stop.

Then, it is better to get out of that classic definition of Probability and modernise our idea of *expectation of the future Events* to the relatively modern Bayesian viewpoint. The expected Risk that a single non-labelled bottle pass to the Market, when consecutively inspected by five independent gaussian measurement systems, results still much lower than 0.001 %.

Non-adherent seals check

Some of the products include labels adherent to the top of the closures, whose function is to evidence that the closure has not been opened. Not all of the seals are correctly applied and, due to the particular geometry, uneasy to identify *in-the-Machine*. To evidence also slightly non-adherent seals, it is possible to increase their visibility by mean of compressed air. The air blow forces the seals to rise enough to enter in the photo scanner light beam.

Locating and inspecting in-the-Labeller

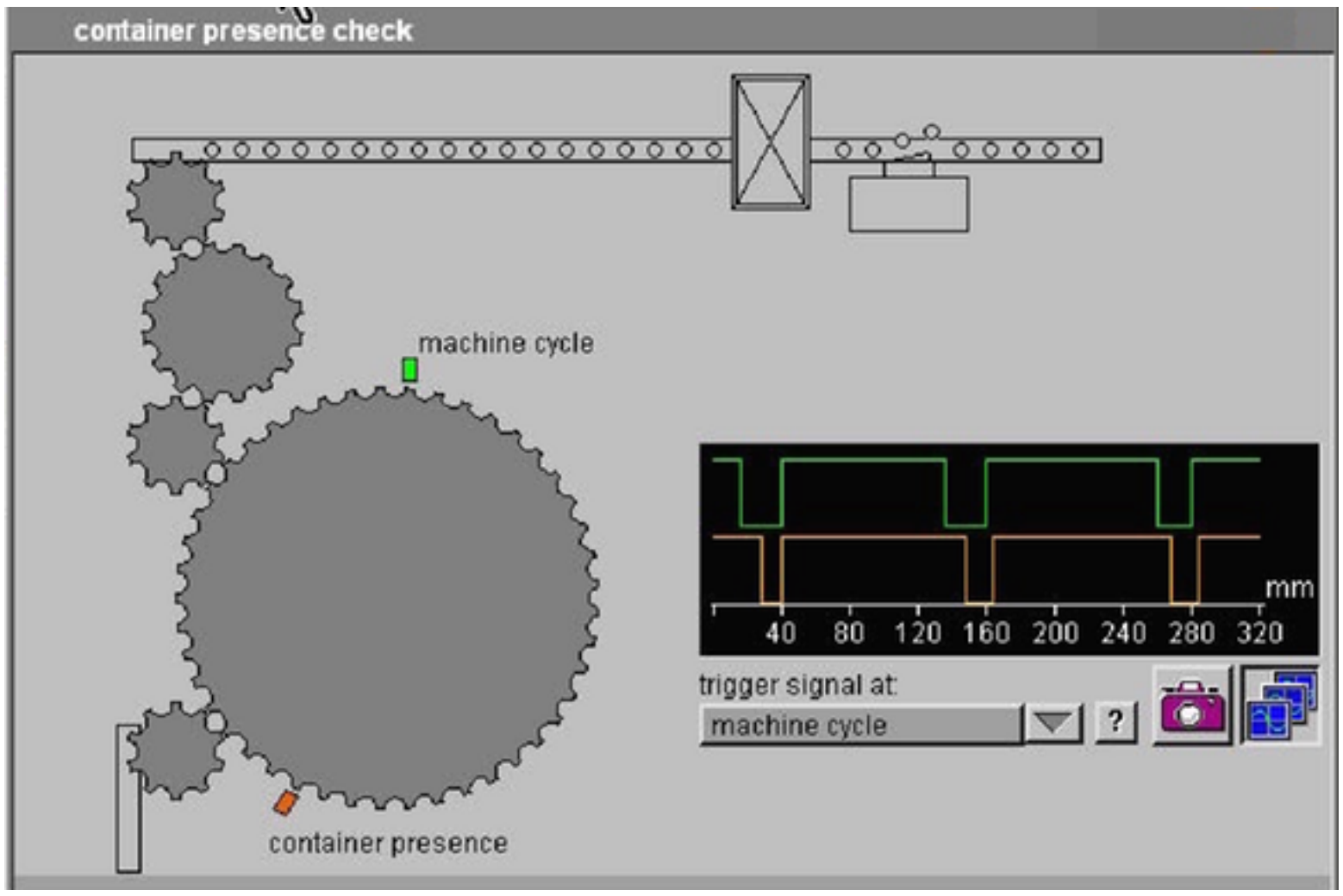
Typically, the Label Presence inspectors having synchronisation sensors and inspections *in-the-Labeller Machine,* have their main cabinet installed immediately at the outfeed of the Labeller machine. There is an excellent reason for this positioning: to limit the amount of non-labelled bottles each one time there is a serial fault created by one or more of the Labeller's labelling stations. The Electronic Inspector tracks the defective

non-labelled container mixed in the flow of the others, by mean of a serie of inductive or optic sensor set in the Labeller Machine's carousel and *at-the-Conveyor* outfeeding the Labeller's outfeed star wheel.

In-the-Labeller Machine the role of basic reference for all distances, there measured in units of Labeller's Pitch, is played by a virtual Trigger. It is obtained by the falling edge of the Machine Cycle sensor, all times a Container Presence sensor signal is associated, in-the-Labeller Machine until the Transfer Point. As a matter of fact *"How many Labeller Machine steps"* is a distance value which can be used also out of the Labeller. Be used in the initial meters (however <2.0 m) of the outfeeding Conveyor, if this is straight and does not present any cause for bottles' sliding. One of such parameters exists for each one inspection.

Labeller Synchronisation sensor

In the Labeller it exists a synchronization sensor indicating the rotary plate no. 1, named Labeller Synchronisation sensor.



Machine Cycle (green) and Container Presence sensor signals (orange), as seen by an Electronic Inspector in a Labeller running at 60000 bottles-per hour. Visibly, the Containrer Presence sensor signal is a short one. A Container shall be considered "Present" when the signal's duration (low phase, zero volt, equivalent to a logic " 1" in this NPN logic) shall result at least 2 ms long. The scale of the image is expressed in millimetres, because of the presence of an Encoder. Then, they are millimeters of Distance equivalent to seconds of Time

Machine Cycle sensor

Then a Machine Cycle sensor, providing a pulse each single pitch of rotation of the Labeller's carousel. Filler Synchronisation, Machine Cycle and Container Presence are a reference for all the Labeller, as seen by the viewpoint of the electronic inspector.

Container Presence sensor

A third one, named Container Presence sensor, is a true inspection and not a synchronization sensor. It detects the mere presence of a bottle entered in the Inspector's Shifting-Register. Machine Cycle and Labeller Synchronisation are signals always surely infeeding to the Inspector as a consequence of the Labeller's revolution. But, a Labeller can rotate also empty, and that's why a Container Presence sensor is necessary. Container Presence sensor is vital to discriminate two cases (or, states)

otherwise impossible to separate.

Alternative cases when no label has been detected applied, and:

1. a bottle is present;
2. no bottle is present.

Transfer Point's relevance

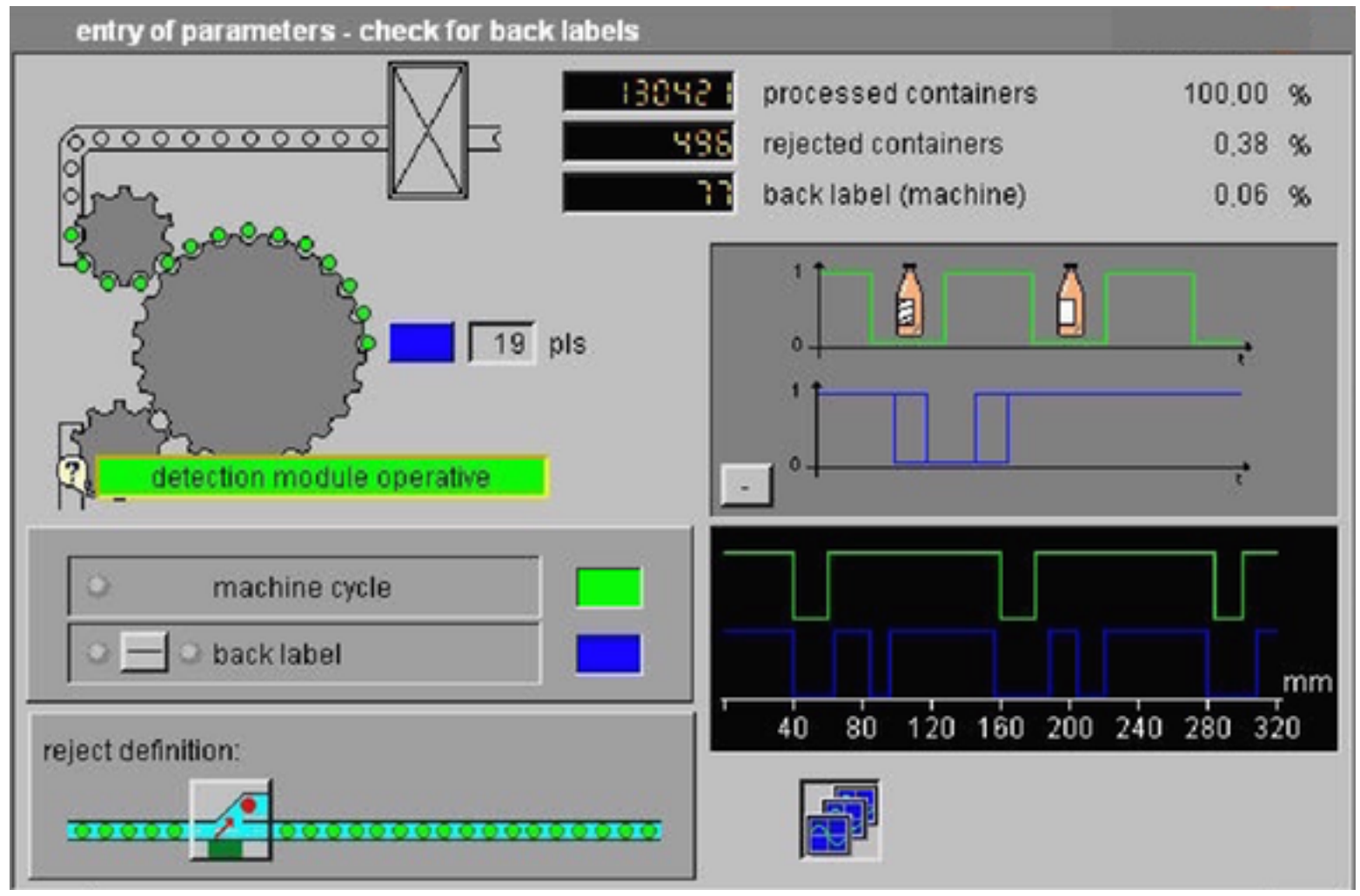
The number of steps from the inspection to the Transfer Point is programmed. On the Transfer Point, it terminates the Machine Cycle and it starts the shifting-register area: as yet seen, there lies a virtual trigger. Transfer point is the point where the Labeler (or Filler) outfeed starwheel starts to leave the container on the outfeeding Conveyor, part of the inspector shifting-register. More precisely, it corresponds to the vertical projection, onto the conveyor surface, of the center of a container lying in a position a few millimeters before it starts to be released to the outfeeding conveyor.

How-many millimeters are *"a few"* ?

An amount x: $$x < 2$$

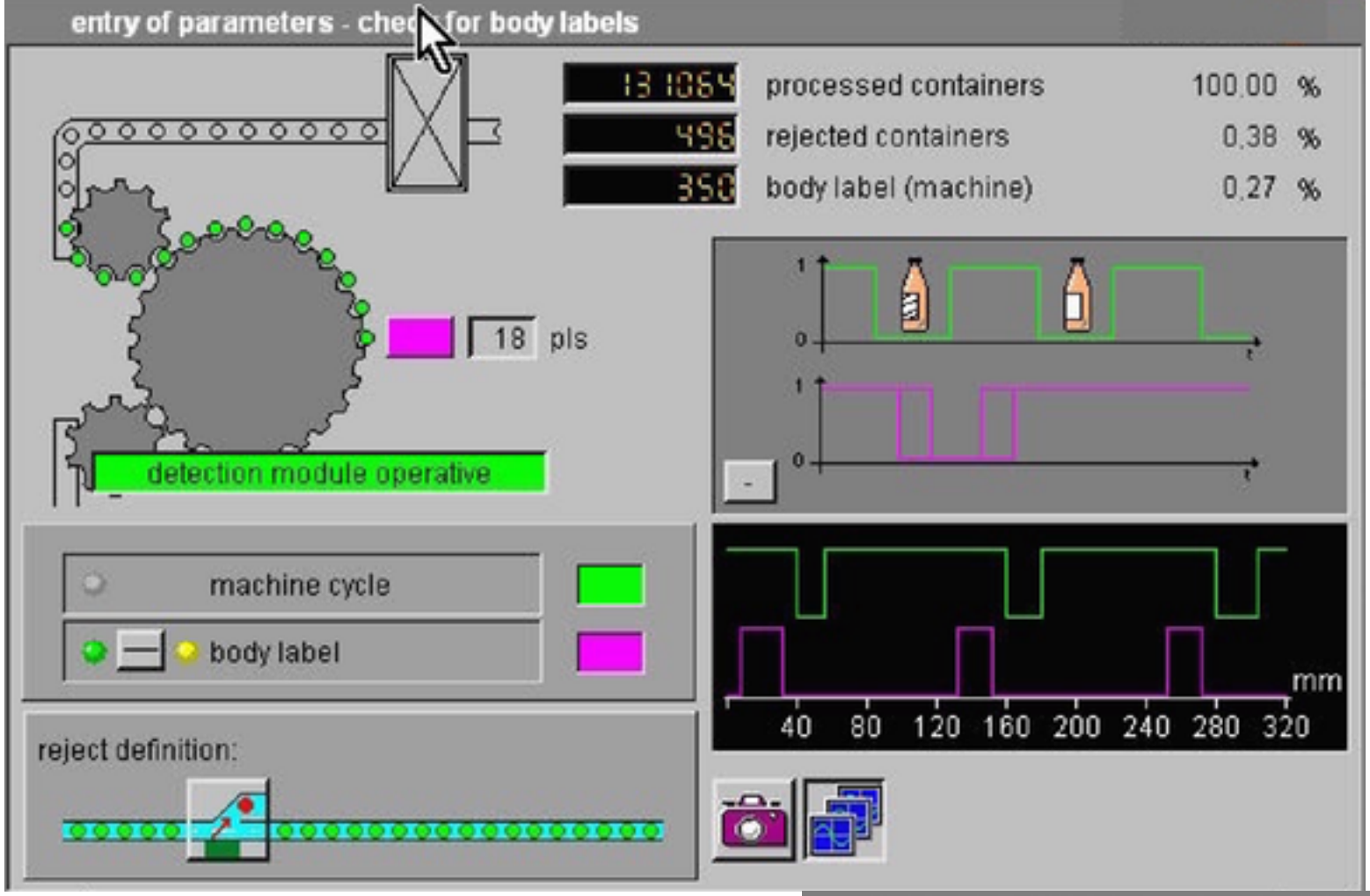
preventing the otherwise progressively increasing False Triggers, accumulated due to wearing of the Labeller Machine starwheel vans and of its axial fixing and bearings.

Four typical label inspections in the Labeler carousel are represented below as blue-, violet-, red-, light blue-coloured signals, respectively corresponding to Back-, Body-, Neck- and Foil-inspections:

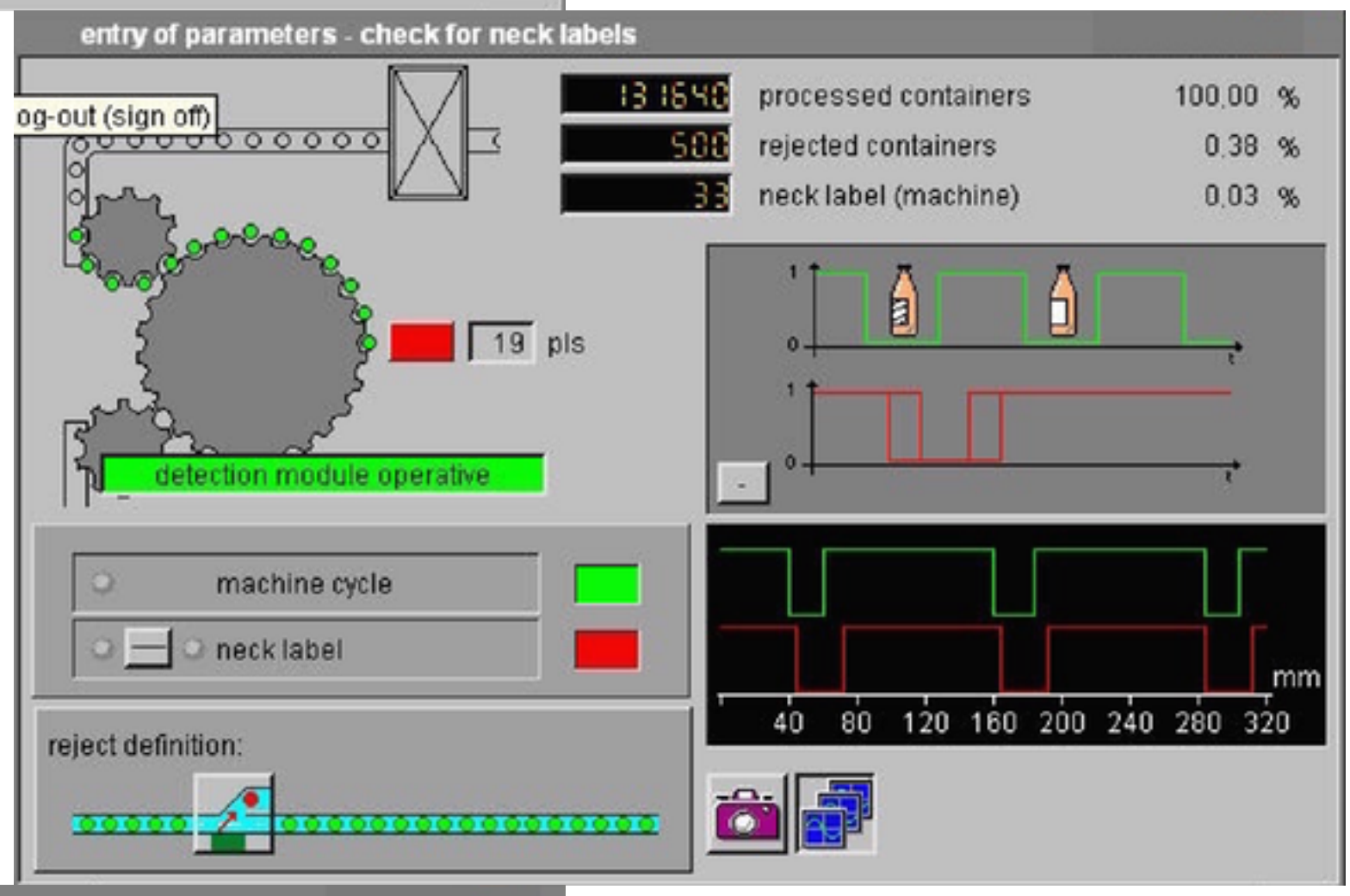


Back label signals, referred to the falling edge of the Machine Cycle sensor, adopted as point zero to measure distances along each one individual step. The multiple blue colour signals indicate the superposition of several negatively affecting causes: oscillations, nonlinearities, reflections, insufficient or excessive retro-diffusion by the label, labels too dark or too clear, inspection during bottle rotation, etc.

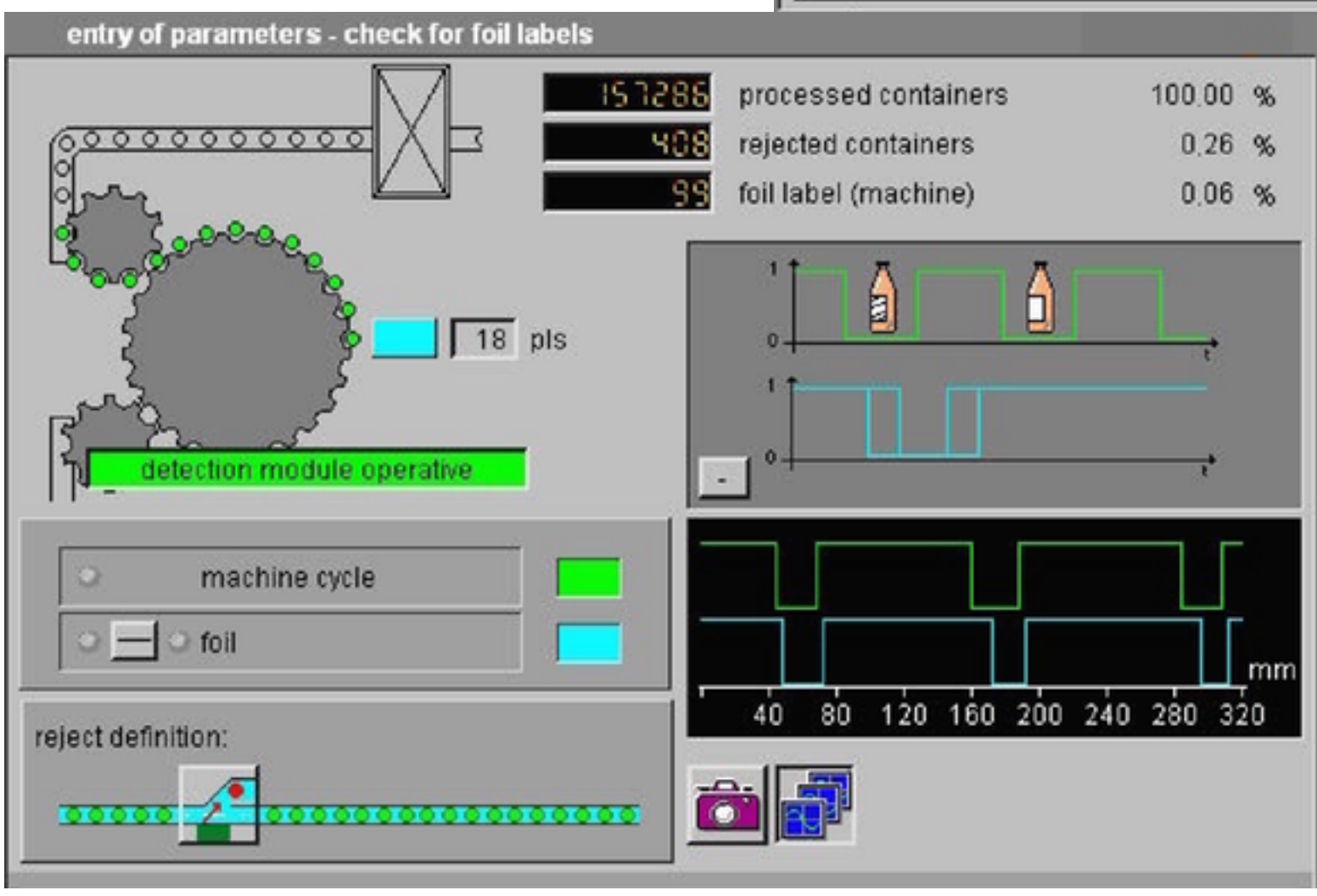
Body label signals, referred to the falling edge of the Machine Cycle sensor, adopted as point zero to measure distances along each one individual step. Visibly, Body label signal has a low phase (Signal "1" in this NPN logic) asting too long. Its falling edge erroneously starting before, rather than after, Machine Cycle sensor falling edge. Thus indicating superposition of several negatively affecting causes: excessive gain of the Photoscanner, Photoscanner's nonlinearity, excessive retro-diffusion by the label, labels too clear, etc.



Neck label signals, referred to the falling edge of the Machine Cycle sensor, adopted as point zero to measure distances along each individual step



Foil label signals, referred to the falling edge of the Machine Cycle sensor, adopted as point zero to measure distances along each individual step



In this Labeller they appear erroneously installed white-coloured brushes.

***Erroneously*, because set after the area devoted to Foil Presence inspection. Then, as visible, the same brushes were removing lots of aluminium foils glued with not enough glue. Defective bottles undetected and terminating to the Market. Problems solved by mean of an uncommon modification of the Electronic Inspector original design. We moved the Foil Presence inspection photo scanner to Labeller's outfeed star wheel, then after the brushes**

Tracking in-the-Labeller and at-the-Conveyor



Why Containers' Triggering is a vital subject

To let the Reader of these notes fully understand why all of the Triggering subject is developed in so many pages in this web site, there is to remark that:

1. **the identity of whatever object is its most fundamental information.** It makes no sense to speak of the “defective status of a container” in presence of ambiguity about “what container” is defective. In other words, containers’ Tracking, is much more important than whatever inspection, say whatever measurement of one of the physical properties of these objects;
2. when comparing Food and Beverage Packaging Industry with the Pharmaceutical Packaging Industry, we discover that the former with few exceptions discards as *dangerous* the rejection over an external Conveyor of the containers detected “defective” *in-the-Machine.* Following Pharma safety standards and customs, detection and rejection have to happen both *in-the-Machine.* The rejection has not to happen out of its Shifting-Register, one truly satisfying the requisites of rigidity and impossibility of the containers’ sliding out of the cells them attributed. Pharma Industry refrains to operate like Food and Beverage Packaging Industry operates following the OEMs and Vendors’ design choices.

“It makes no sense to speak of the “defective status of a container” in presence of ambiguity about “what container” is defective”

Sliding conditions

One time a bottle is released by the Labeller out feed starwheel to the outfeeding Conveyor, all of the information regarding the bottle contained in its accompanying data sheet, is received by one or more **Tracking Triggers.** Just one Trigger, in this case named Trigger 1, if the Electronic Inspector main cabinet and related Rejector are close to the Labeller Machine out feed starwheel's Transfer Point. How much close ? No more than 2.0 m from the Transfer Point. A distance which could be 1.0 m longer, if the fastest container format expected to be treated is a relatively slow one, e.g. <0.8 m/s. At least six conditions make a container prone to slide, during its release by the Machine starwheel and along its journey through the Conveyor.

Each one of them is sufficient to let a container slide that much (>1/2 container diameter) which is enough to clear its identity in the Inspector Shifting-Register:

1. distances >2.0 m,
2. curves between the Inspector main cabinet and the Rejector,
3. speed is >0.8 m/s,
4. light containers (<0.8 kg),
5. equipments (e.g., air blowers, twists, etc.) whose action perturbates containers’ motion, exists along the Conveyor, interposed between Machine’s Transfer Point and following tracking Trigger,

“Pharmaceutical Industry, ...with few exceptions discards as dangerous the rejection over an external Conveyor of the containers detected “defective” in-the-Machine… both detection and rejection have to happen in-the-Machine”

6. Conveyors' cross-overs,

If any or more of these reasons conditions the installation's layout, a serie of Triggers becomes vital to assure the conservation of the original data written in the container's accompanying data sheet.

Machine-Conveyors-Inspector synchronisation

Whatever the case, then also for relatively slow speed Labellers (<1.0 m/s), it is vital to synchronise the *ramp-up* and *ramp-down* phases of the Labeller and of the out feeding Conveyor, so that their speed difference results always <0.1 %.

0.1 % is a value knowingly close to the nonlinearity limit of the commercial Frequency Converters. Say the equipments regulating the speed of the motors in the Labeller and in the Conveyance systems. As an example, 0.1 % of divergence between bottle *in-the-Labeller* and same bottle *at-the-Conveyor,* at a speed of 1.5 m/s are 1.5 mm. 1.5 mm may appear a small divergence. But it is the maximum which can be allowed to be, keeping apart the today rare cases where containers' speed is relatively slow (<0.8 m/s).

Containers' speed, being related to the containers' kinetic energy following a quadratic law, enhances the slidings' occurrences and then their negative effects.

False Triggers and Data Sheets

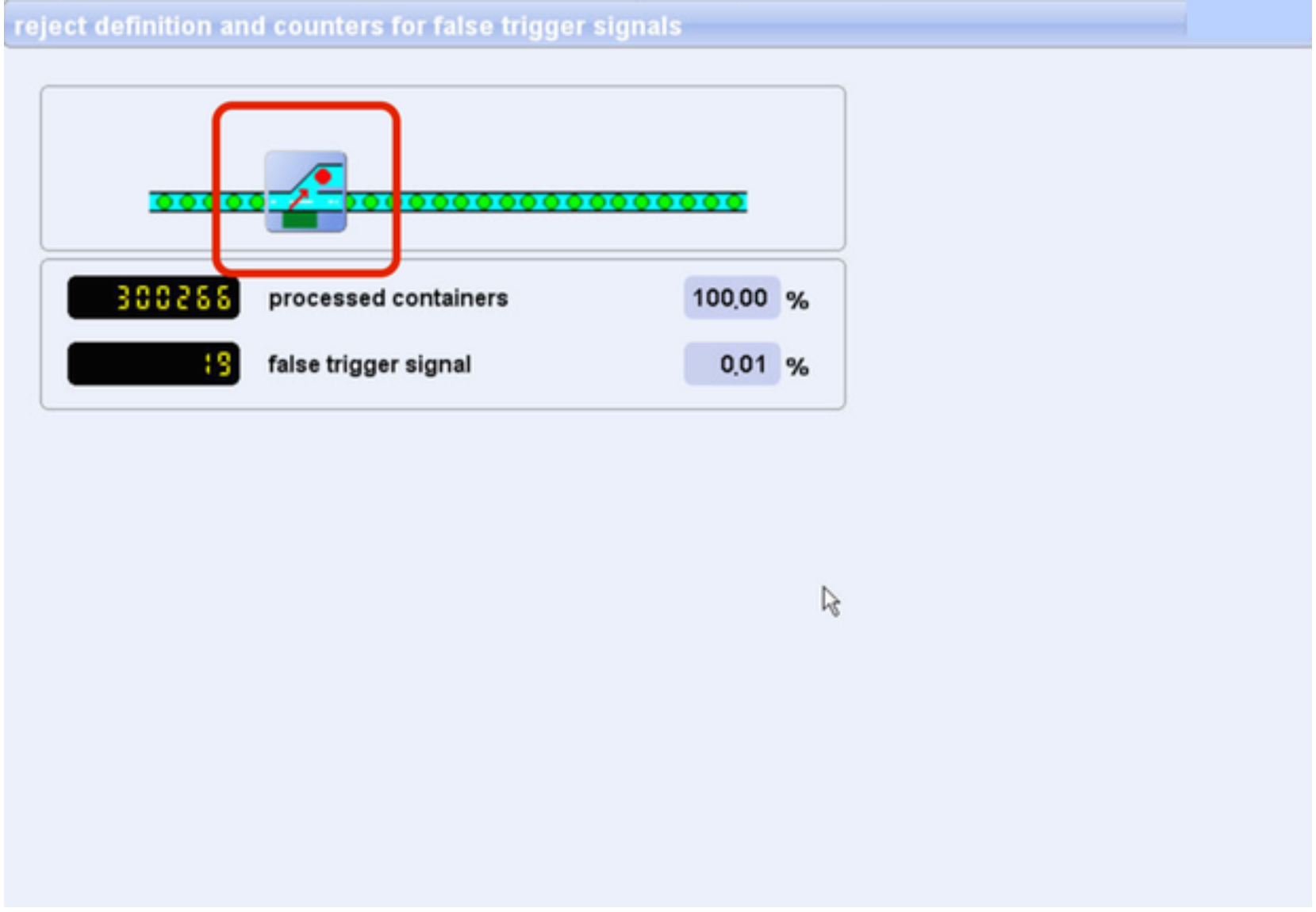
The Trigger controlling the Rejector, say the last one immediately before the Rejector, shall be exposed to count *False Triggers*, corresponding to bottles whose identity is unknown because lost. *False Triggers* which, in your own full interest, have to be absolutely be rejected by the Inspector, also if part of them corresponds to correctly labelled bottles.

How many of them has to be expected corresponding to correctly labelled bottles, then False Rejects ? A quite precise answer is given by the Inspector Counter menu for False Triggers, visible below as 0.01 %. Exactly that shall be the portion of the total False Rejects due to Falsely Triggered bottles. The mere existence of the Container Presence sensor shall force this rejection. Do not forget what seen above about the Transfer Point of the Labeller Machine's out feed starwheel.

False Triggers Reject Definition. Similar menus for the Tracking Triggers exist whatever be the Vendor of the electronic inspector, however with differences in the colours, logos and motives. The icon indicating a deviation out of the Production flow (a rejection) has to look like in the red box "enabled". This way, the falsely triggered bottles shall be rejected. In a Label Presence Inspector *in-the-Labeller,* whatever different setting you could encounter is a deliberate decision to send to the Market also bottles detected defective because not labelled. Have you requested or authorised this ?

We refer to the necessary synchronisation of the Transfer (or, release) Point better than possible and with a positional error <2 mm. A difference between Labeller and of the out feeding Conveyor >10 mm, say a divergence >0.67 %, implies well visible false rejects caused by falsely Triggered bottles. The only case where it's admitted a divergence > 0.1 %, is during the Labeller's emergency stops. Special and not frequent cases when to reject some correctly labelled bottles is the best action we can take.

Containers' tracking starts under the control of a virtual Trigger based *in-the-Labeller Machine* and has to continue over the following Conveyors, until after the Rejector and the Reject Verification Trigger set immediately after the Rejector. A problem



today widespread is that the relative porcentage of the Electronic Inspectors *in-the-Machine* (Label, Fill level or Cap Inspectors) really operating like in their Order and their Design, is reduced to minimal porcentages, never seen along past two decades.

A synchronisation respectful of the contractual superior limit given to the False Rejects (False Positives) and to the defective and not rejected containers (True Positives), whatever their nature, **implies a limit also on the False Triggers.**

False triggering causes

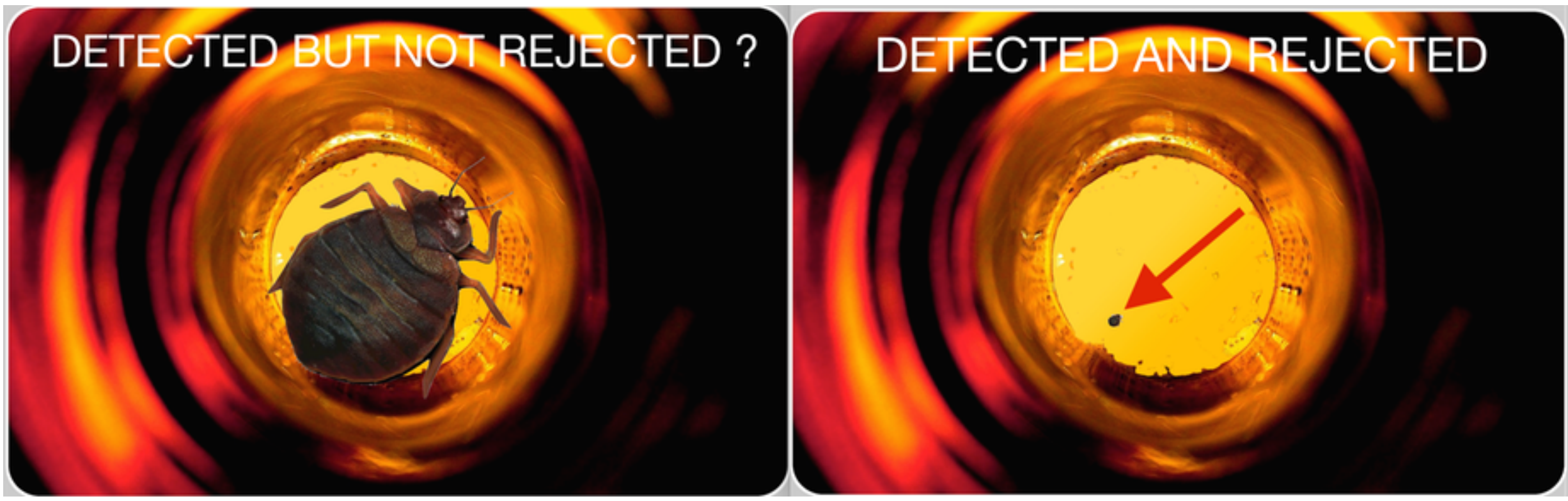
A **Falsely Triggered container**, is a PET- or glass-bottle, a can, keg, crate or case, which lost its *“identity”* due to several causes and between them:

1. outfeed too early or too late by the precedent Labeller-, Filler-, Capper-, Closer-, Seamer-Machine:
 1. typically indicating a *commissioning error* in the synchronization Machine-Inspector,
 2. rarely due to a hardware fault of one of the detectors,
2. slided forward, anticipating its arrival front of the following Trigger,
3. slided backward, posticipating its arrival front of the following Trigger,
4. manually
 1. introduced in the flow of containers,
 2. removed out of the flow of containers,
5. arrived so inclined front of the following Trigger, that it terminated to occupy a precedent or following cell in the Electronic Inspector’s Shifting-Register,
6. flagging label or foil, emulating a container neck arrival front of the following Trigger,
7. defective Tamper Evident Ring of plastic caps, emulating a container neck arrival front of the following Trigger,
8. broken splinters, whose passage is registered front of a Trigger.

“Identity” originally attributed in the data sheet, later accompanying each one of them along their journey through the Electronic Inspector’s “Machines” and “Shifting-Registers”.

Expensive In-the-Machine Inspectors silently

downgraded to cheap Standalone



Do you know how is it possible to have the behaviour described by the figures above ? At right side, the same identical bug as left side, whose size is 60 times smaller. Label, Container Presence, Torque, Bottle Burst or Asepticity inspections, when accomplished *in-the-Machines* require special Commissioning cares. If the good-practices and rules are not observed, you'll see a strange behaviour. Small defects detected and rejected, the very big too detected but strangely and visibly not rejected. In the meantime, …little or nothing of false rejects. Kind of operation hinting to an illusory *in-the-Machine* electronic inspector whose Shifting-Register is losing containers

The Electronic Inspectors, whatever their Vendor, are built in two alternative configurations:

1. standalone,
2. in-the-Machine.

Standalone configuration

Standalone configuration is by far the cheapest. 2-5 times cheaper than the *in-the Machine.* It does not include any connection, sensors, inspections, detectors nor logic relation with a precedent Labeller-, Filler-, Closer- or Seamer-Machine.

Its:

- tasks are limited to handle a single Shifting-Register, rarely a couple of them;
- hardware is reduced to the minimum, typically one Trigger sensor over which the unique Shifting-Register is logically built, inspections and a rejector.
- fitting, wiring, starting and commissioning are accomplished in a limited time and, not being particularly complex tasks, they do not require the typically few available top-skilled service technicians.

In systhesis: when configured to operate *Standalone,* all Inspectors imply an installation task that all of the Optoelectronics' service technicians fulfil.

"*Actions to hide never commissioned synchronisation of Inspector, Labeller and Conveyor, also implying a permanent impossibility for the Bottler to fulfill the triadic quest for:*

1. *minimum losses,*
2. *minimum downtimes,*
3. *maximum rejection of defects and safety"*

In-the-Machine configuration

The Electronic Inspectors with locating positions and/or inspections *in-the-Machine* (Labeller-, Filler, Closer-, Seamer-Machine) are complex and their:

- tasks extended to handle several Shifting-Registers, typically two minimum;
- hardware is maximised, several Trigger sensors (inductive and optic) over which the various Shifting-Registers are logically built, many inspections and frequently more than one Rejector.
- their complexity is reflected in their pricing, always a factor 2-5 more expensive than the corresponding models operating *standalone*,
- years of practice, trainings, deep and true comprehension of the Shifting-Register's concept, are pre-requisite to an accomplished Commissioning. Commissioning honouring the Contract between an OEM or Vendor and a Food and Beverage Bottling and Packaging Company, also respectful of a row of legal requirements imposing, as an example, that the Machine Safeties cannot be left systematically disabled to the unaware Customers.

Human-factor does matter

Commissionings can only be named and underwritten that way in a worksheet whose siognature is asked you when:

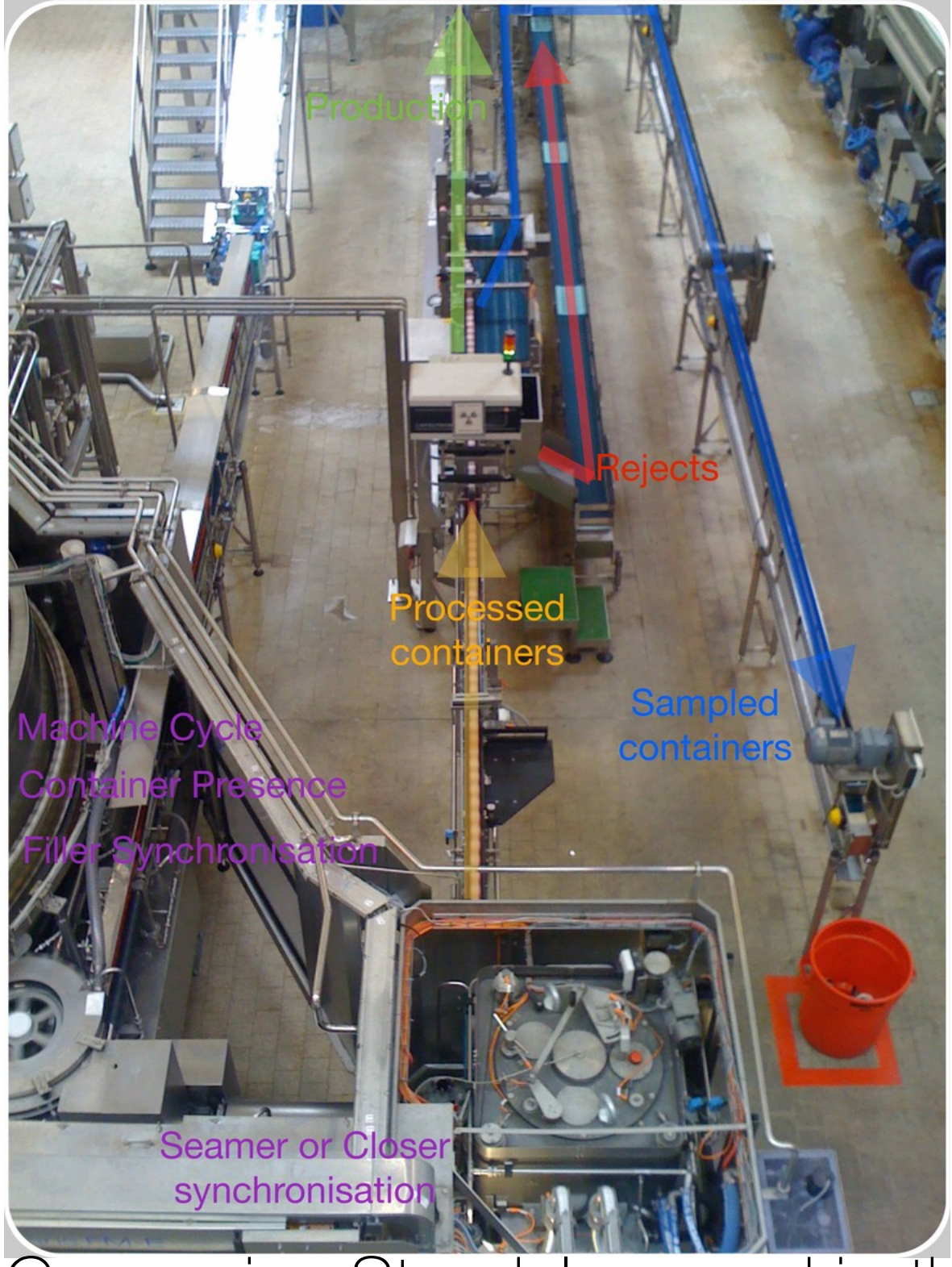
- honouring the Contract between an OEM or Vendor and a Food and Beverage Bottling and Packaging Company,
- respectful of a row of legal requirements imposing, as an example, that the Machine Safeties cannot be left systematically disabled to the unaware Customers.

We are suggesting the Readers that the service technician’s skills are part of the final added-value of the Electronic Inspector, because he is the one who shape the future of the equipment. Unavoidably, World’s most expensive and higher Quality Electronic Inspector, if left in the hands of some of the worst technicians, always performs much worse than World’s cheaper and lower Quality Electronic Inspector, when left in the hands of some of the average-skilled technicians of the World.

“...service technician’s skills are part of the final added-value of the Electronic Inspector, because he is the one who shape the future of the equipment.

World’s most expensive and higher Quality Electronic Inspector, left in the hands of some of the worst technicians, always perform much worse than World’s cheaper and lower Quality Electronic Inspector, left in the hands of some of the average-skilled technicians of the World”

▲ *Standalone* (left) versus *In-the-Machine* (right) configuration. At left side depicted two *Standalone*-configured Full Container Inspectors, each of them processing ~46000 cans-per-hour. Their Binary Classification task reduced to a single deviation of the red-coloured Rejects out of the green-coloured Production flow. All Containers entering each Inspector and going to be attributed an identity in the unique Shifting-Register by the unique Trigger, here named and orange-coloured as Production. At right side, the *In-the-Machine* inspection system receives 4 additional digital inputs by 2 Machines, here a Filler and a Seamer, which in general may also be Capper, Closer, Labeller or Blowformer. Also an additional outside blue-coloured for the Advanced Sampling. A much deeper comparison of the two configurations, one only known to the Vendors, regards the installation (mechanical, fitting, wiring, start-up, commissioning, training) timing. However difficult may this result to be imagined, the *in-the-Machine* configuration at right side needs >16 man*days when the *Standalone* at left side, needs <4 man*days. Meaning that the complexity underlying the In-the-Machine delivery to the Bottler is >4 times bigger than for a relatively easy *Standalone* inspector. Figures representing the full can inspection systems assuring the Quality of a 92000 cans-per-hour Canning Line





Comparing Standalone and in-the-Machine installations' pricings

How to predict what should be the pricing of an Electronic Inspector's *installation,* say its fitting, wiring, start-up, Commissioning and Operators' Training ?

Examing *a posteriori* many hundredths of different installations of Electronic Inspectors in Beverage Bottling Lines:

- where the above named installation activities had really been made, and made the only way the laws let them be valid in your country, because conformal to Safety rules and other technical good practices it is possible to see that a relation really exist,
- in different countries,
- part of Projects of Bottlers in competition (example, Coca-Cola vs. PepsiCo, AB InBev and SABMiller), whose Quality standards are different,
- configured with all of the existing spectrum of inspections,
- processing all existing kinds of containers (glass-, PET-, PRB-bottles, metal cans, crates and cases, etc.),
- from a wide range of productions, from 8000 til 92000 containers-per-hour,

regression analysis shows an approximate but straightforward relation deriving be the comparison of the prices of the equipments, when the *installation* activities are not included. The installation pricing factor has empiric origin, nor we'd imagine what another way could be imagined to observe tendential relations which can only be obtained by linear regression studies *a posteriori*.

As an example, if a Full Bottle Inspector costs 8000 € , ~10000 $ (weighs net 18 kg) is mainly because that amount is proportioned to the sum of the values of its mechanical, pneumatical, optoelectronics and documentation components.

Another kind of Full Bottle Inspector of that same Vendor, priced ten times more, i.e., 80000 €, ~100000 $ (weighs 138 kg) shall need *installation* activities extended approximately to a duration >4 times longer than 8000 € model, needing just 3 days.

Superior models cost ten times more than the basic because they sport many more functions and optionals to:

- install (Rejectors, Triggers, cables, sensors, etc.),
- fit,
- wire,
- start,
- commission,
- train the staff.

Basic questions submitted to you own critical thinking:

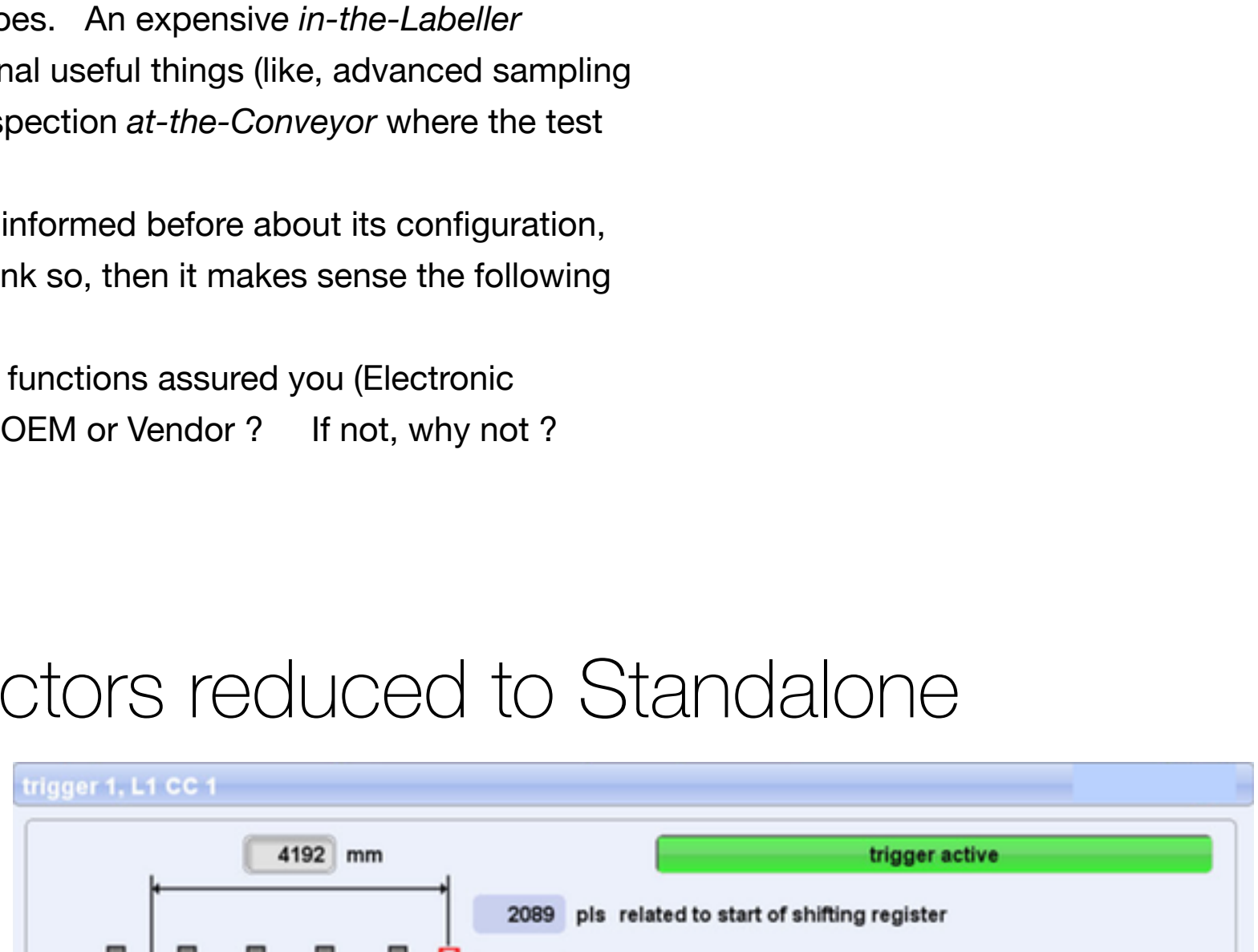
1. an Electronic Inspector needing >12 man*day of activities in your site, has been (strangely) delivered you after just 5 man*day ?
2. What let you feel comfortable with the idea that its configuration is what you paid for ? What techniques you used to test it ?
3. Maybe some test bottles had been passed one hundred times before to decide ? If this is the case, you have to know this is the kind of inspection a cheap *Standalone* Electronic Inspector does. An expensive *in-the-Labeller Machine* is paid to do many more additional useful things (like, advanced sampling or inspection *in-the-Labeller*) than just inspection *at-the-Conveyor* where the test bottles have been introduced.
4. Would you order a new car without to be informed before about its configuration, motor and performances ? We don't think so, then it makes sense the following question:
5. Have you received a precise listing of the functions assured you (Electronic Inspector's Technical Guarantees) by the OEM or Vendor ? If not, why not ?

"…possibility that the in-the-Machine Electronic Inspector you acquired is in-the-Machine only in its expensive mechanics, hardware and firmware.

But that later was not Commissioned in-the-Machine rather Standalone"

In-the-Machine Inspectors reduced to Standalone

Containers' Tracking Triggers 1, 2, 3, 4, 5. [Similar menus for the Tracking Triggers exist whatever the Vendor of the Electronic Inspector, however with differences in their motives, colours or logos].



Setup of *"additional containers not accepted"* and *"loss of containers not accepted"* has mandatorily to be identical to that in a red colour box. Be wary of setups you may discover presenting *"additional containers accepted"* and/or *"loss of containers accepted".* In a Label Presence Inspector *in-the-Labeller,* they'd correspond to a deliberate decision to send to the Market also bottles yet detected defective because not labelled. Have you ever requested or authorised in a written way to leave disabled Machine Safeties and/or to counter Vendor's Technical Dept. written design recommendations like these ?

Food and Beverage Companies managers' triadic quest for:

1. minimum losses,
2. minimum downtimes,
3. maximum rejection of defects and safety.

implies that all Quality Control equipments have to be at least as performant as they were declared by the respective Vendors in the Technical Guarantees part of that Offer which had been accepted by the Bottler.

But, the Electronic Inspectors' Shifting-Register is the most complex kind thinkable. It joins rigid and banal Shifting-Registers, like those of the rotary machines (Filler, Labellers, Closers, Cappers, Seamers) to the anelastic deformable Shifting-Registers (Conveyor's belts) where containers can freely move themselves, rather than be firmly kept blocked in the Shifting-Register's cells.

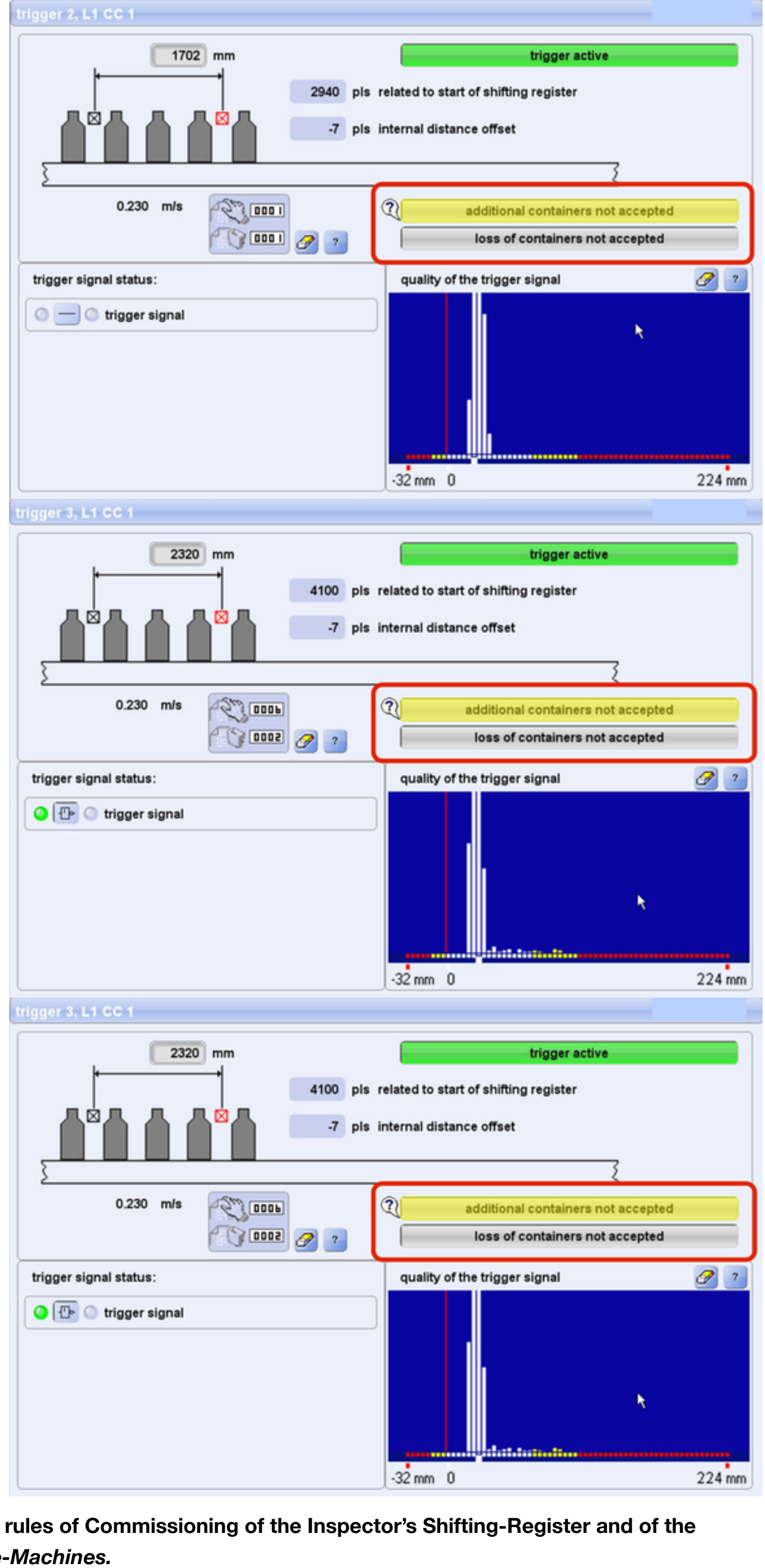
Have you seen macroscopic defects passing through the Inspector, not detected ?

We refer ourselves to bottles:

- **semi-empty,**
- **without closure,**
- **without all of the labels.**

Missing rejections made strange by the fact that, simultaneously extremely smaller defects are correctly detected and rejected, as an example:

- **2 mm underfilled bottles,**
- **closure inclined or too high for a few millimetres,**
- **bottles rejected because one of the labels is misplaced (but present) for 1-3 mm.**



Commissioning's Rules

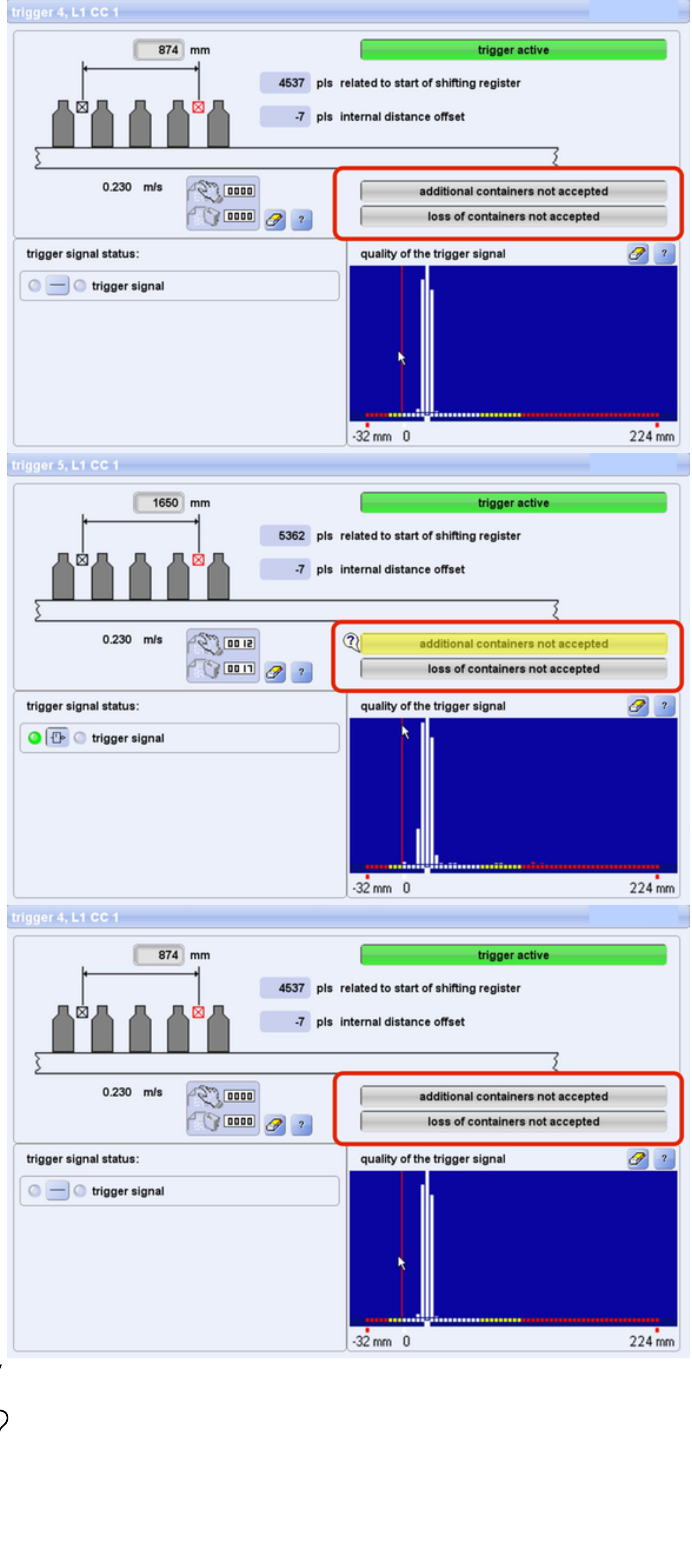
All these cases hint to
a **parameterisation** (or, setup) **violating basic rules of Commissioning of the Inspector's Shifting-Register and of the positions of the Inspector's detectors *in-the-Machines.***

Written rules diffused by Vendors' Technical Departments. Rules clearly defining what is the most basic "inspection" in whatever Electronic Inspector: the constant control and cross-check of each *container's identity in the Shifting-Register*.

If the identity, the identification of an object is ambigous, how and why could we consider it non-defective and ship it to a Customer ? This can be obtained *forcing* determinate “bits” to do what Vendors’ Technical Dept. and rationality do not want absolutely be done, nor should ever be done when owning the necessary know-how.

Small defects correctly rejected

and some extremely big defects are not ?







Have you repeatedly observed that an extremely small defect detected and rejected and that, on the opposite, extremely bigger defects also detected but were later strangely not rejected ? And, simultaneously, no false reject of a correct bottle happens ? Then, it is highly probable that the expensive *in-the-Machine* (Labeller, Filler, Closer, Capper, Seamer) electronic inspector you acquired, had been parameterised forcing it to operate as a cheap *Standalone* model

We have records of too many Inspectors *in-the-Machine only in their expensive hardware*, encountered forced to operate *Standalone* and not *in-the-Machine.*

If the scenario described above in bold letters corresponds to what is being observed, then the problem affecting the Quality of your Company does not derive by missing detection, because of inspections' sensitivity not adequate to the defects.

Banally, a bottle nearly always rejected because:

- its plastic cap is 1 mm too high,
- one of the labels is 2 mm misplaced,
- 1 mm underfilled,

implies that completely missing caps or labels and under- or over-filling are detected well over 3-standard deviations. Then, they'd had to be rejected if…, if the Inspector's Shifting-Register has not undue programmed parameterisations forcing that outcome when the container loose its identity. If cases like these have yet been and continue to be observed in your Beverage Bottling Line, then there is a high possibility that the *in-the-Machine* Electronic Inspector you acquired is *in-the-Machine* only in its expensive mechanics, hardware and firmware.

But that *later was not Commissioned in-the-Machine.* Rather, as it'd be a much cheaper model operating *Standalone at-the-Conveyor.*





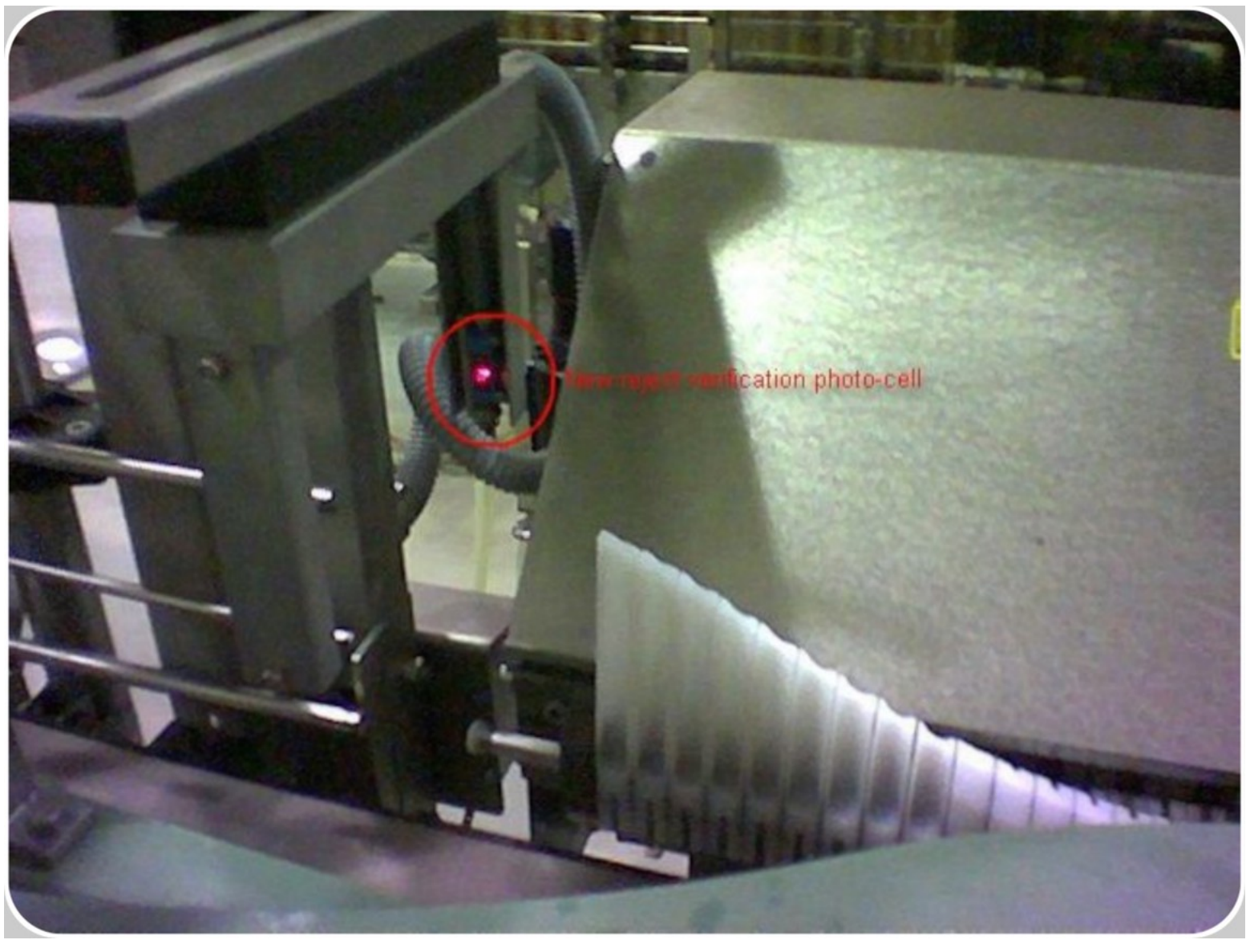
To downgrade an expensive *in-the-Machine* (left-side) electronic inspector in a cheap and basic *Standalone* (left-side), is much easier than to commission the *in-the-Machine*. Easy to do and difficult for the Bottler to perceive

Systematic actions

~70 of the past >100 electronic inspectors *in-the-Machine* in their hardware and firmware, have been and are presently being discovered and recorded on the opposite operating *Standalone,* because of a well defined pattern of actions:

- **targeting the False Triggers Reject Definition***, a* particularly important Machine Safety of the Electronic Inspector, so not to reject the containers without identity, including those defective;
- **targeting the operational definition of the Triggers** (1, 2, 3, 4, 5). All containers “lost” or “additional” forced to be considered “correct”. The opposite than what an expensive Electronic Inspector *in-the-Machine* has to do;
- **targeting the Reject Verification Trigger, leaving it disabled** (e.g., marked like Trigger 5 in the menus above at right side). Reject Verification Trigger which is the most important Machine Safety;
- **aimed at hiding the never commissioned synchronisation of the system Inspector + Labeller + Conveyor**, also implying a permanent impossibility for the Bottler to fulfill his quest for:
 1. minimum losses,
 2. minimum downtimes,
 3. maximum rejection of defects and safety.
- **extended to the Inspector's hardware** in some cases, so to let a green colour traffic light keep calm the dubious Bottlers, forcing artificially off the red colour traffic light. That permanent alarm status that the Electronic Inspector’s inner diagnostics should have showed if those *jumps* (or, bridges) should not have been made.

Above, at right side, a sequence of menus translating in a practical real case of Inspector in-the-Machine, how it looks like the correct sequence of Tracking Triggers. It is a basic and fundamental set of instructions: there are additionals.





Take extreme care that the definitions evidenced in the red boxes have to appear:

- ***“additional containers not accepted”***
- ***“loss of containers not accepted”.***

No other setup is conformal to the Technical Department of the Electronic Inspectors’ Vendors and for obvious reasons.

Different setups, like:

- ***“additional containers accepted”***
- ***“lost containers accepted”***

strictly and only mean that the bottles (or, cans) who have lost their own identity in the Inspector’s Shifting-Register, have to be considered “correct bottles”. Apply this to an Electronic Inspector with Label Presence inspections *in-the-Labeller Machine.*

It means to send straight to the Market all bottles without labels, also without any one label, if these bottles have lost their identity. To loose the identity, it is enough to slide one-half of the bottle diameter and/or, to be in the Shifting-Register of an erroneously commissioned Electronic Inspector. What surely happen very frequently in an Inspector when misrespecting any of the recommendations listed above in the section: “Locating and inspecting in-the-Labeller” and others.

Actions in some cases, extended to the Inspector's hardware, so to let a green colour traffic light on keep calm the dubious Bottlers, switching artificially off the red colour traffic light that the Electronic Inspector’s inner diagnostics was in the meantime trying to show

Reject Verification Trigger is the most important Machine Safety. Systematically targeted also the Reject Verification Trigger, leaving it disabled. In the menus above at right side it appears marked as Trigger 5.

Root Causes

1. **Vendor’s Service Technician**. If the Service Technician is not capable to commission the *in-the-Machine* inspector existing at least in its hardware and firmware, several way-outs known us Experts remain open to let the Inspector *“looks-like it is operating in-the-Machine”* when in the reality it is not.

We recorded >70 of these occurrences along >100 *in-the-Machine* inspectors'.

2. **Maintenance Dept. Staff**. Alternatively, the observed permanent anomaly could have origin in an erroneous reprogramming of a correct parameterisation, by someone part of the Bottling Maintenance Dept. Staff. However someone owning an access level high enough to have the possibility to change these parameters.

 We recorded <5 of these occurrences along >100 *in-the-Machine* inspectors.

3. **Production Operators.** Possibility exists but it was never observed nor one case.

4. **Random, spontaneous changes of the parameterisation.** They are excluded. These "errors" are not randomly affecting all of hudredths or sometimes thousands of parameters, rather always and only a few very well definite. If it'd be bad luck, we'd be forced to say that after 2004 "mr. Bad Luck" dresses very powerful lenses when targeting the *in-the-Machine* Electronic Inspectors to downgrade them to *Standalone*.

A precise, factual and evidential attribution of the Root Cause of these undue parameterisations, can be easily obtained after controlling the historic memory of the Data Saving operations in each Electronic Inspector. Simply checking the setup of these decisive parameters on the date when Vendor passed to Bottling Company the equipment declaring it complete and corresponding to the Purchase Order.

TRUSTe Privacy Policy

Graphene®

Food and Beverage Electronic Inspection Experts

Label Presence inspection





Commercial photoelectric proximity switch

Introduction

The interaction of a material irradiated by electro magnetic waves, implies three different effects: reflection, refraction and diffraction. Light irradiated by a LED most commonly operating infra-red (IR) at a wavelength of ~1µm, or visible red colour (see figure below). Light source contained in the same package of the sensor, typically a photo-transistor, whose out feed enters an operational amplifiers. Light irradiated to the label, from where it'll be later reflected, refracted and diffracted. Just a small fraction of the light incident to the bottle external sidewall shall be retro-reflected diffused toward the sensor, lying a few millimeters far from the LED source visible in the figure at left side. Setting, as sensitivity threshold, a value intermediate between the retro-reflected signal when label is present, and the value measured when no label is present, it results possible to discriminate the presence or absence of labels on the container.

Label Inspection



(../label_inspection.zip)

Flash animation, 45 MB, ZIP

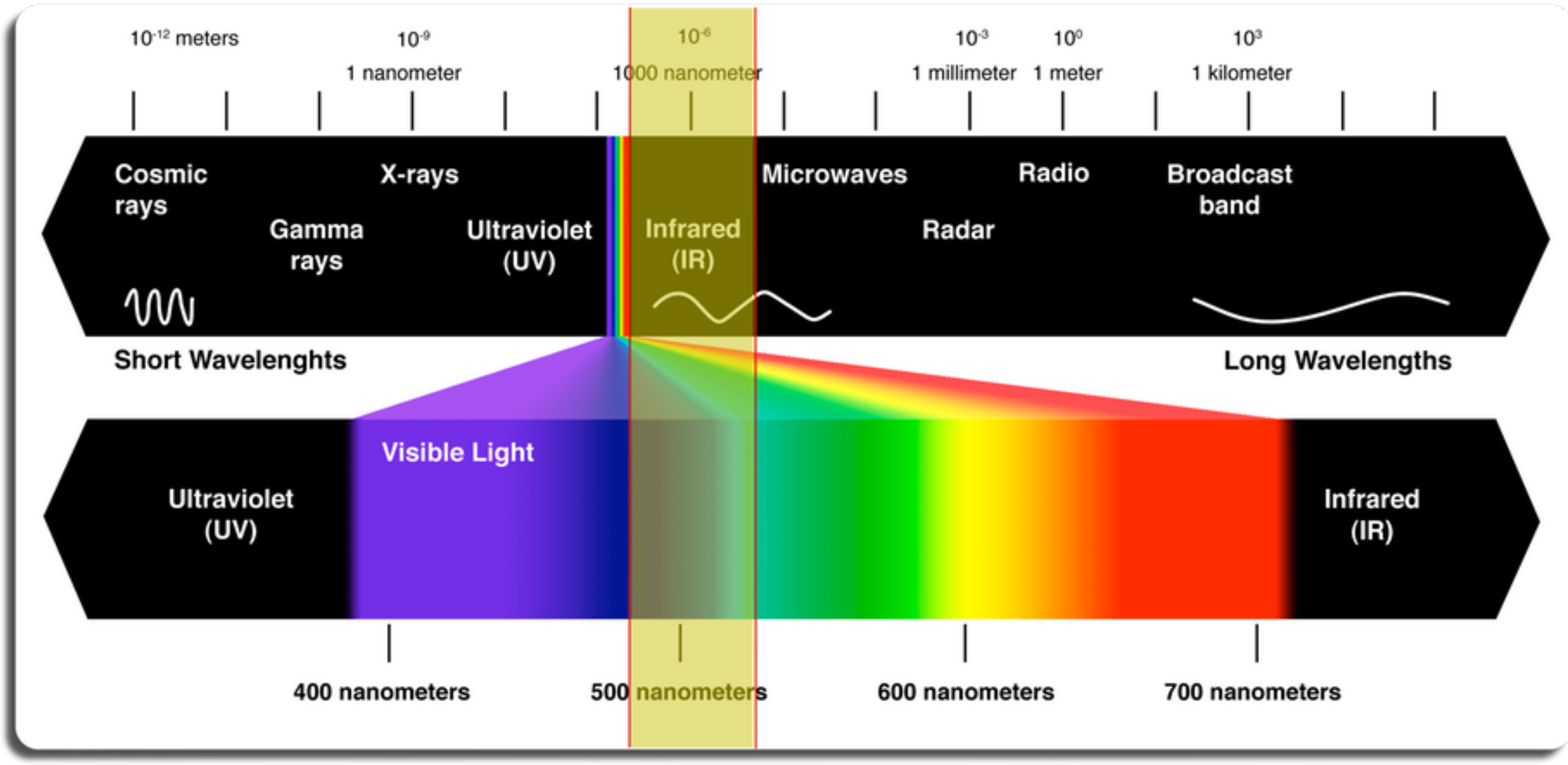
After download click index.html



(../label-inspection-.pdf)
(../../../../designer-portal/root-cause-analysis/root_cause_analysis_problem.pdf)

59 pages, 71 MB

(../label_inspection-2.epub)



Spectral position of the infrared (IR) band adopted by photoscanners devoted to Label Presence Inspection

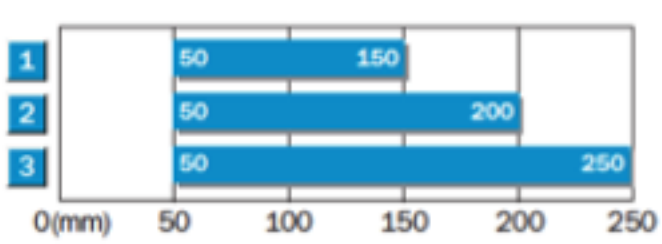
How Label's Colour influences the Scanning Distance

Refer to the figure below showing the behaviour of a red light emission photosensor in the range of distances in between sensor and label: (50 – 250) mm, the one typically used for label presence inspection.

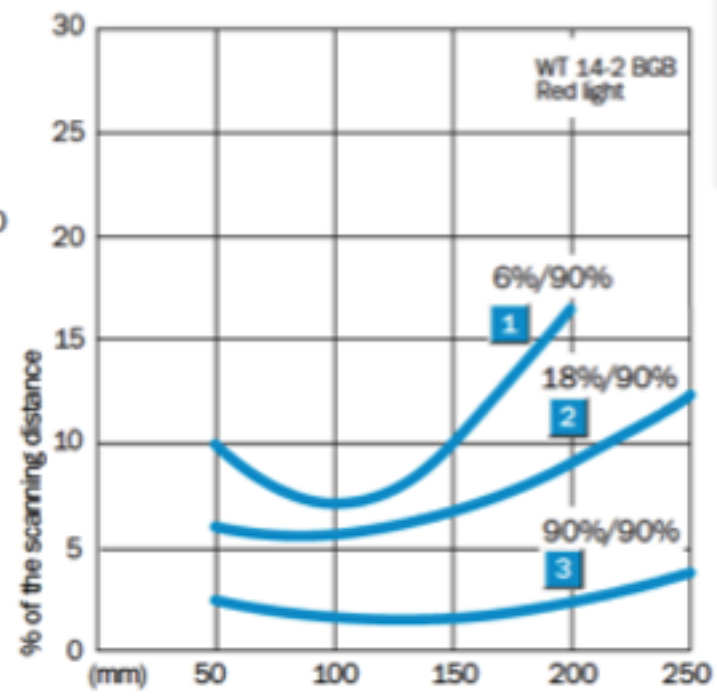
Three different re-emissions percentages associated to labels whose colours lie in three different tones:

1. 6 %, black,
2. 18 %, grey,
3. 90 %, white.

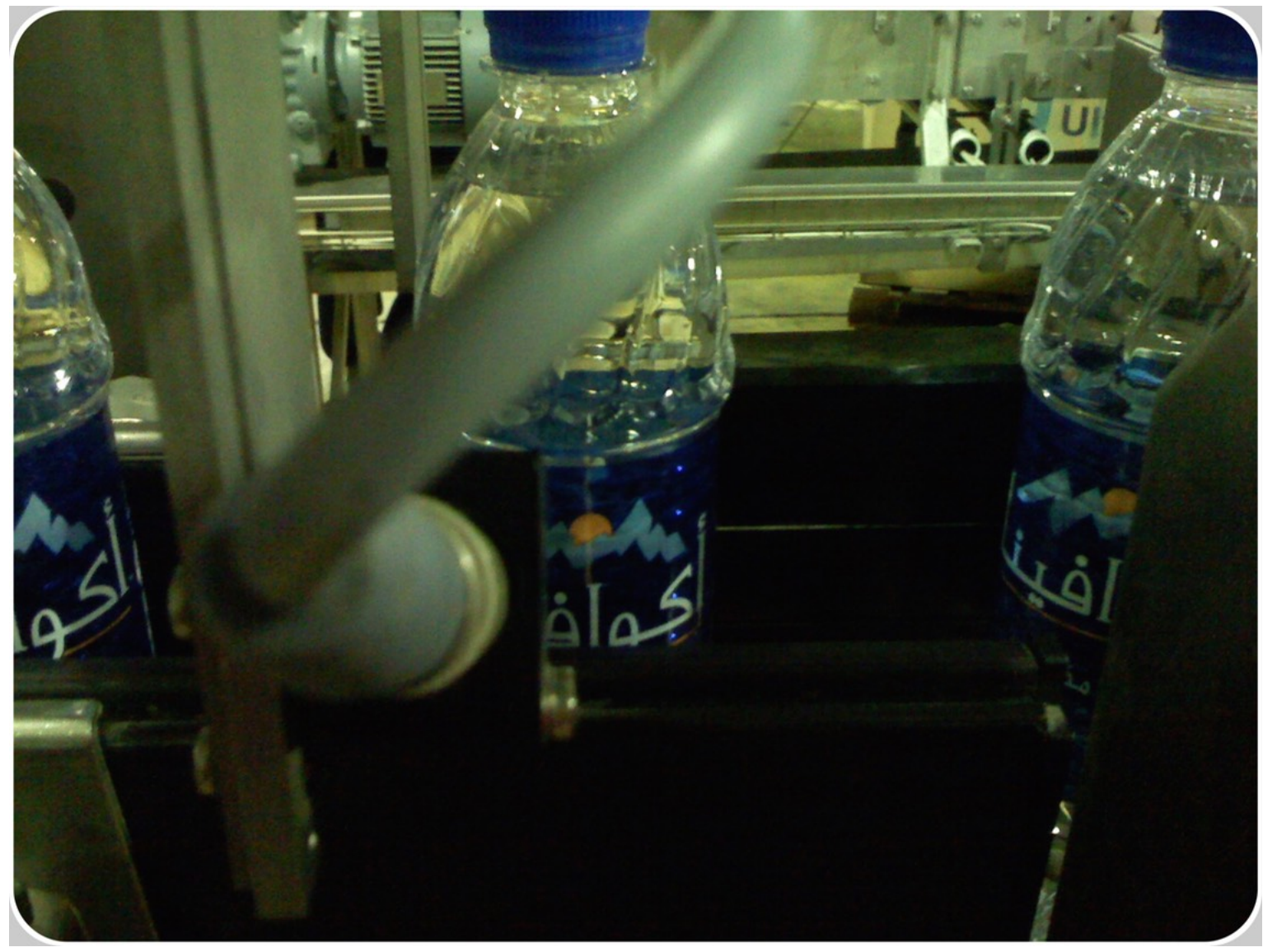
Re-emission characteristic curves of the photoscanner above at left side, when illuminating a target with red light, for a range of distances (50 –250) mm. Visibly, only different distances sensor-label can optimize the detection following the colours' differences



1 Scanning distance on black, 6 % remission
2 Scanning distance on grey, 18 % remission
3 Scanning distance on white, 90 % remission



By the characteristic curves, it is possible to see that a black colour label, 6 % of re-emission, shall be optimally detected with an incoming signal sufficient to switch the outfeed contact for a scanning distance sensor to label 6 % of 250 mm. If the material is black colour, 6 % of re-emission, the optimal distance for switching shall be 100 mm and the truly useful range shan't be wider than 150 mm. If the material is white, 90 % of re-emission, the switching shall be assured thru all range (50 – 250) mm, optimized around 125 mm.



Semi-transparent labels. Their coloured area particularly dark, because of its blue dominant. We saw ourselves compelled to direct the photoscanner toward the only one white colour detail written in Arab language in an Electronic Inspector operating in a PepsiCo franchisee in Oman, Persian Gulf. Observe the angle <30º we adopted. An higher angle increases favourably the Signal-to-Noise relation but it was not possible to use it here, again because of the labels' semi-transparent nature, implicitly causing low re-emission

What above is directly hinting to several potential problems, when adopting the cheap label inspection with analog photo-sensor:

- in the inspector there is *no way to adjust the distance sensor - label* when changing format and label's colour;
- *no way to select the colour* of each one format in the Bottling area: it is typically a Marketing Dept. who chooses their colour;
- the *labels are curved and moving*, rather than flat as those used by the tests' base for the re-emission graphic above. Implying that in the Electronic Inspectors there is time available only for a few measurements. As a consequence, just a few values of the random variable shall be registered in conditions far from what the definitions of a "good measurement" in Physics.

Yet these factors alone imply that the signal outcoming by the same photoelectric switch in the same electronic inspector, may be extremely wide for a clear label or extremely short for a dark. Due to the fact that when signal duration is < 2 ms, these (signals) are interpreted as: *"No label"* signals by the inspectors, we have to be ready to understand the root causes for sometimes impressive false rejects.

How many sensors to use ?

They exists 3 types of label-container geometrical relations, requiring different amounts of photosensors. The amount of sensors in the Table at right side assumes labels fully reflective and non-flagging.

Label	Sensors
All-around (360º)	1
> ½ of container circumference (> 180º)	2
< ½ of container circumference (< 180º)	4

If semi-reflective, or partially transparent like in the figure below, their amounts have to be double than those marked in the table for cases: (360º, < 180º) say in an amount of 4.

▶ **Sensors/Label/Container relation for one fully reflective non-flagging label. If more than one label has to be detected, the amount marked in the column "Sensors" has to be proportionally increased**

To apply four photosensors rather than one, increases only (1 - 5)% the total price of the electronic inspector, due to the low cost of the sensors. This, when of the highest Quality photoscanners on the Market, cost ~230 € each (~300 $), and average cost being 40 €.

As photoscanners of the *"highest Quality on the Market",* we are meaning those (like, e.g. Omron's model E3S-CD16):

- specifically designed for the transparent and semi-transparent labels used by the Beverage Bottling Companies;
- operating with fuzzy-logic;
- including a microprocessor, and not just an operational amplifier;
- using polarised light, rather than non-polarised;
- stainless steel case (IP65), and not plastic;
- NPN and PNP, and not only NPN;
- with glass front window, and not plastic easy to scratches;
- with output short-cut protection;
- preventing mutual interferences with other photoscanners;
- designed 15 years ago, and not nearly 40 years ago.



▲ **Semi-transparent labels on PET bottles**

The two figures below at right side, show an example where 2 photosensors (of good Quality) were not enough to detect semi-transparent labels for PET bottles filled with water.

Detection ratio resulted a poor 80 % and false reject 0.01 % for flagging-labels. Flagging-labels being the most frequent (> 90 %) in between all possible types of defect, and also the most difficult to detect too. When choosing a standalone in-the-Conveyor label inspector on semi-transparent labels, it is a must to order the Flagging-Label option totaling 4 photo-sensors. Flags nearly always are oriented downward by gravity. Meaning that the change on reflection, the *Signal*, is observed in the optimal condition only directing the light beam exclusively to the upper side of the labels.

In presence of semi-transparent labels, nor the visible couple of photo-sensors were not enough to prevent false rejects ▼

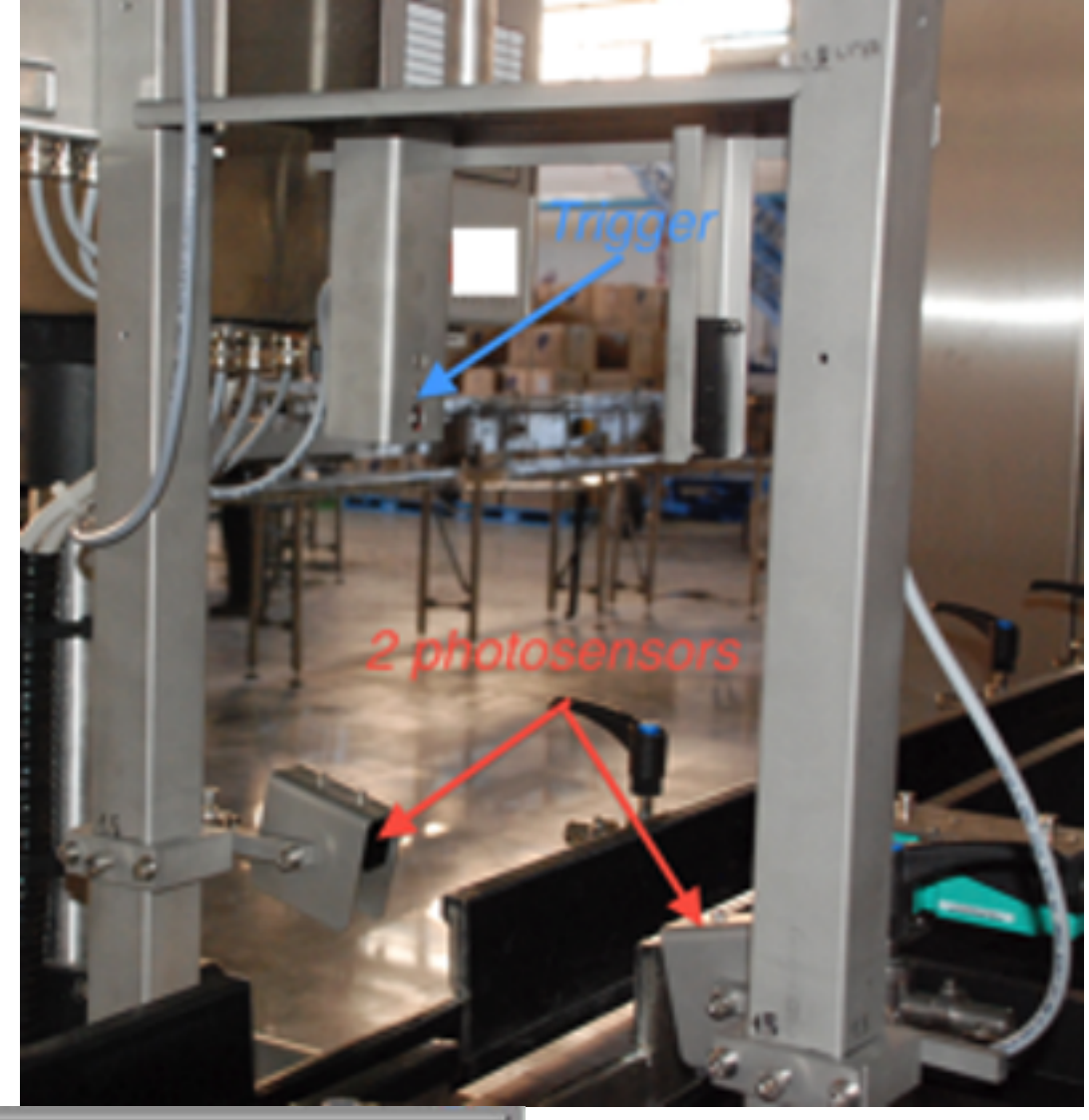
How to adjust sensitivity

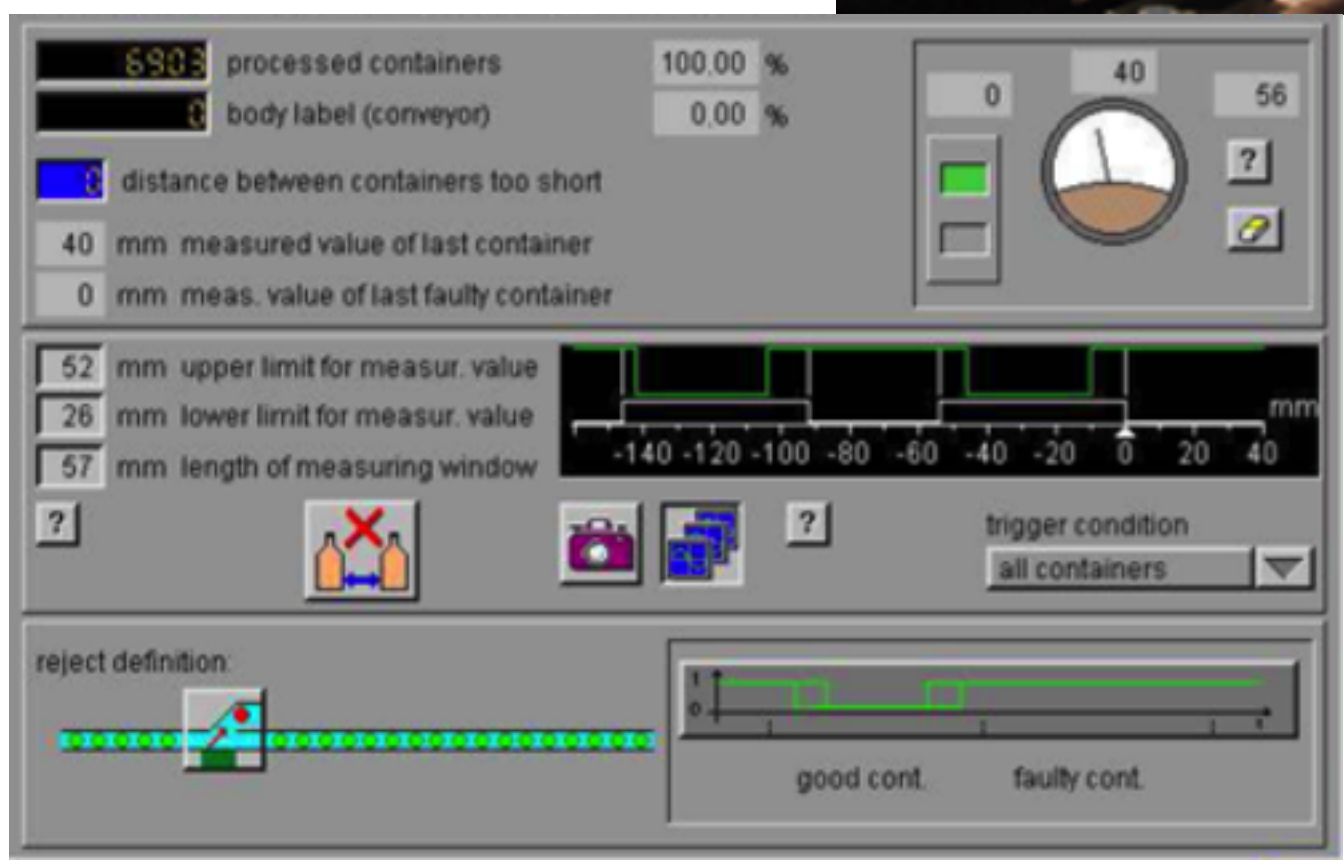
The sensitivity to adjust by mean of the sensor trimmer, has to be kept close to 135°, say one-half of its 270º range, to optimise linearity of the internal amplifier. The angle of the photo-sensor, with respect to the label, has to be in the range (15–35)º to prevent sensor over exposure.

All these conditions can be summed implying an adjustment of the three parameters defining the sensitivity, so that:

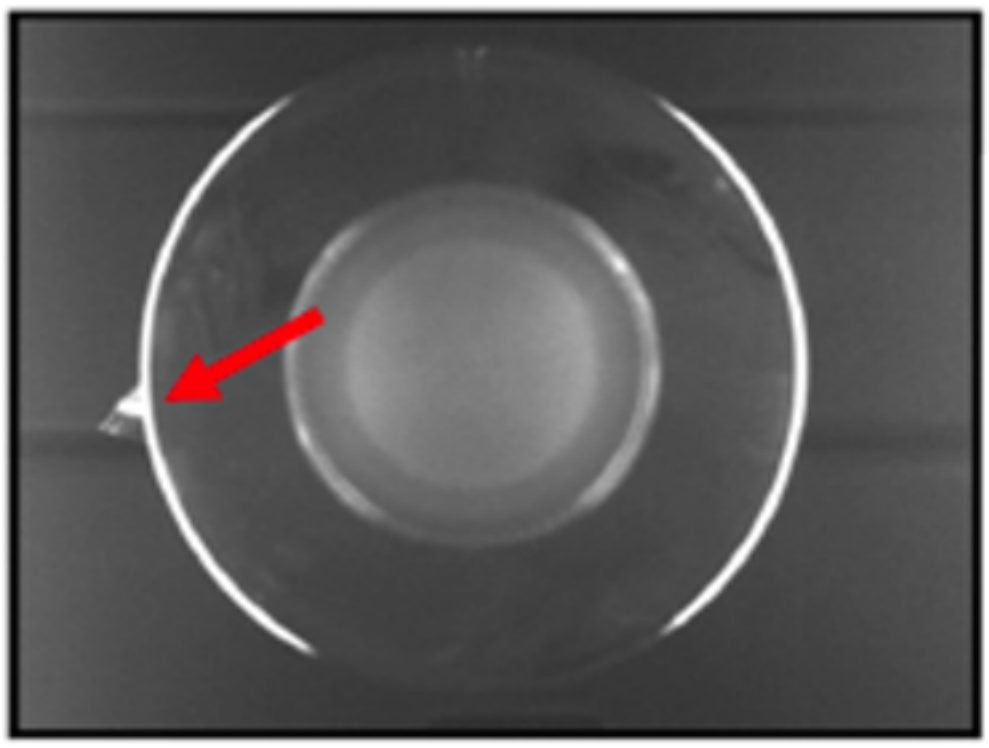
actual value of the measurement < upper limit for measurement value < length of the measur. window

lower limit for measur. value < length of the measurement window < actual value of the measurement





Label inspection parameterization can only be “tailored” to the specific application during commissioning



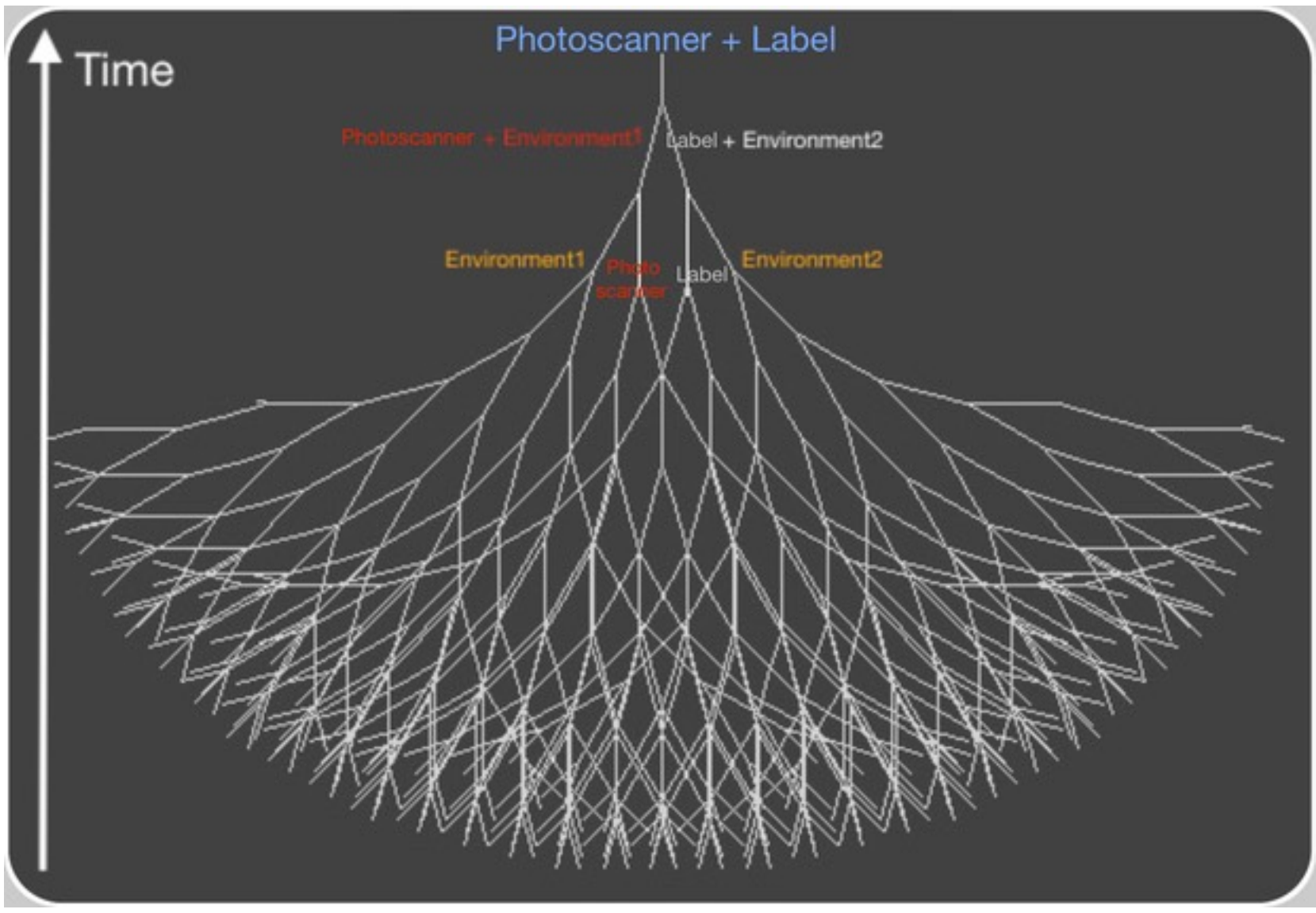
Light beam has to be directed always to the top side of the labels. Figure at left side shows how a camera on top of a bottle with a flagging label.
The erroneously applied label, folded and protruding out of the sidewall contour for approximately 4 mm, is easily detected by a camera.

A label bottle with a label visibly flagging, as seen by a camera

What is a “good Label inspection” ?

The correlated Label-Photoscanner State

As we saw with plenty of details elsewhere in this web site (../../../../services--technologies/physics-of-triggering/Trigger-Physics/index.html), as an example we'll try to determine if a bottle is labelled by mean of a common Photoscanner. Photoscanner including a LED irradiating the container's sidewall or neck, where the label is expected to be, later receiving and processing just a fraction of the reflected diffused waves.



To establish a relation between a label ("Label") and a Photoscanner ("Photoscanner"), both differentially related with the Environment ("Environment1", Environment2"), is necessary Time. Time to transform the previous *state*, in which all possible kinds of correlation of the Photoscanner coexist, in a following *state* in which the Photoscanner is "aware" to be correlated to a label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a cap. Quantomechanical explanation of the measurement process, unaffected by the circularities implicit in the classic explanations. The vertexes represent *interferences*

Until eventual switching its digital output if the diffused retro-reflected waves' intensity is over a threshold level pre-set during commissioning.

To definetely perceive a *correlated Label-Photoscanner State*, they are necessary:

1. **Time, to transform the previous state, in which all possible kinds of correlation of the Photoscanner coexist, in a following state in which the Photoscanner is "aware" to be correlated to a Label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a Label.** The correlation between the two systems, Photoscanner and Label, is progressively established during interaction and proportional to the natural logarithm (ln t) of the interaction time t. An ideal correlation, corresponding to a maximised information of the Photoscanner about the Label, can only be reached allowing an infinite time. The fact we cannot wait for an infinite time causes the measurements' fluctuations, a synonimous of the spectrum of the eigenvalues, resulting in the Electronic Inspector's false positives (false rejects). Time, for what ? Time to transform the previous state, in which all possible kinds of correlation (themselves, superpositions) of the Photoscanner coexist, in a following state in which the Photoscanner is *aware* to be correlated to a Label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a Label.
2. **Interaction between the systems such that the information in the marginal distribution of the object inspected is never decreased**. In a probability distribution deriving by two random variables, we remember that *marginal distribution* is where we are only interested in one of them. Otherwise, we'd have forcedly reduced the sample space where one of the random variables is derived and then, we could not have any more *repeatability* of the following measurements. As an example, this should be the case if we'd erroneously try to use a beam of high energy neutrons, rather than LED's low energy photons, to interact with the Label. The neutrons should modify the molecular structure of the Label, modifying its eigenstates and then the eigenvalues we expected to derive by the measurement.

What precedes is the unique scientific background existing for the fact that also double, triple or quadruple photoscanners, and also if of the best Quality (costing ~300 $ each), can result insufficient to reach satisfactory results. *Satisfactory* in terms of defects' rejection ratio with minimum false positives. Be wary of proposals for systems which could later leave only you and

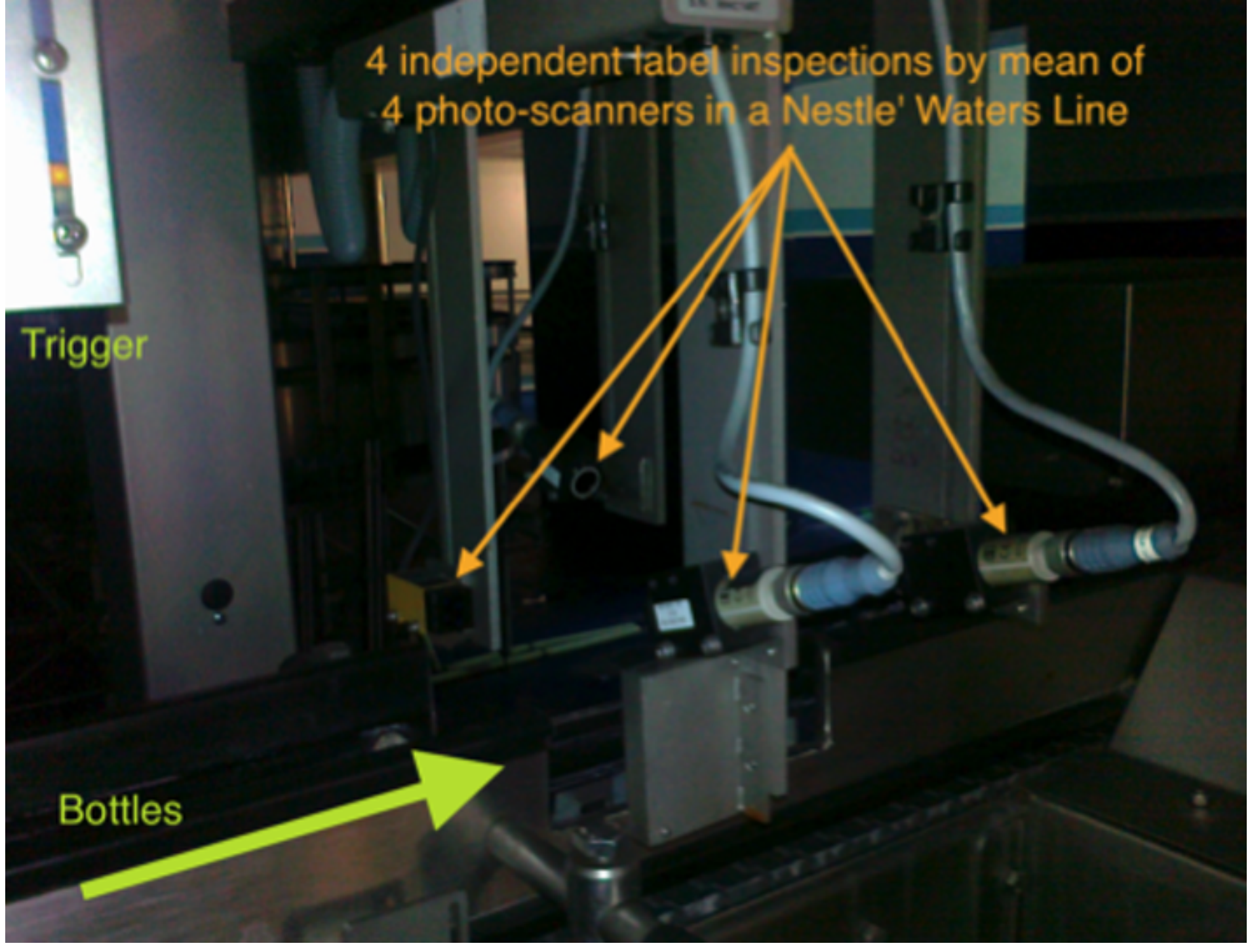
your Company with the nightmare to have the product store, filled with yet palletised flagging-, malpositioned- or missing-labels.

Probability Multiplication Theorem

A different, extremely cheaper approach in the figure below. Here, four independent label inspections check the wrap-around label position by four different places.
Photoscanners' independence being the key to satisfactory performances, without extra-costs, operative complexity and expensive spare parts, always associated to camera-systems.



▲ To detect a Label they are necessary Time and a kind of interaction which do not reduce the information in the marginal distribution of the Label. All times bottle and label share the same material nature like this Russian plastic bottle and label, the application is more difficult and are necessary labels of high re-emission (Baltika OAO, CARLSBERG Group/2014)



Flagging label inspection, by mean of four independent inspections, adopting the cheapest general-purpose photo-scanners. Their outfeeds take advantage of the Probability Multiplication Theorem. Application on PET bottles labelled with semi-transparent labels

Such a design profits of the implications of the Probability Multiplication theorem. Applied to an Electronic Inspector (a Binary Classifier) composed by:

- a set of N inspections, each one identified by the suffix-i,
- whose individual rejects converge to a single Rejector,

the probability that each one of the N inspections fails to detect a single defect is reduced to:

$$\prod_{i=1}^{N} Inspection\ detection\ ratio_i$$

In our case, the probability $P_{1,2,3,4}$ of joint occurrence of four events $1, 2, 3, 4$, any collection of outcomes of an experiment:

- whose respective probabilities are P_1, P_2, P_3 and P_4;
- shaped following the normal (gaussian) distribution;
- reciprocally independent;

is the product of their individual probabilities:

$$P_{1,\,2,\,3,\,4} = P_1 * P_2 * P_3 * P_4$$

Finally, after considering that each one of the N inspections has:

$$0 < \textit{detection ratio} < 1$$

it results immediately evident an impressive reduction on the amount of defective containers falsely considered “correct” (False Negatives), proceeding to the Market.

Case Study

5 Binary Classifiers in a single Label Presence Inspector

As an example, we’ll consider the case of N = 5 (five) inspections, all of them featuring the same individual False Positive (false reject) ratio FP$_i$ < 0.01 %.

Five independent Binary Classifiers, independently acting on a single rejector, whose individual:

- accuracies;
- reproducibilities;
- specificities;
- sensitivities;

are such that the same property of an object is classified with Probability of False Negatives, say the undetected nor rejected but truly “defective” bottles:

$$10.00\ \%$$

Defects’ Detection Ratio

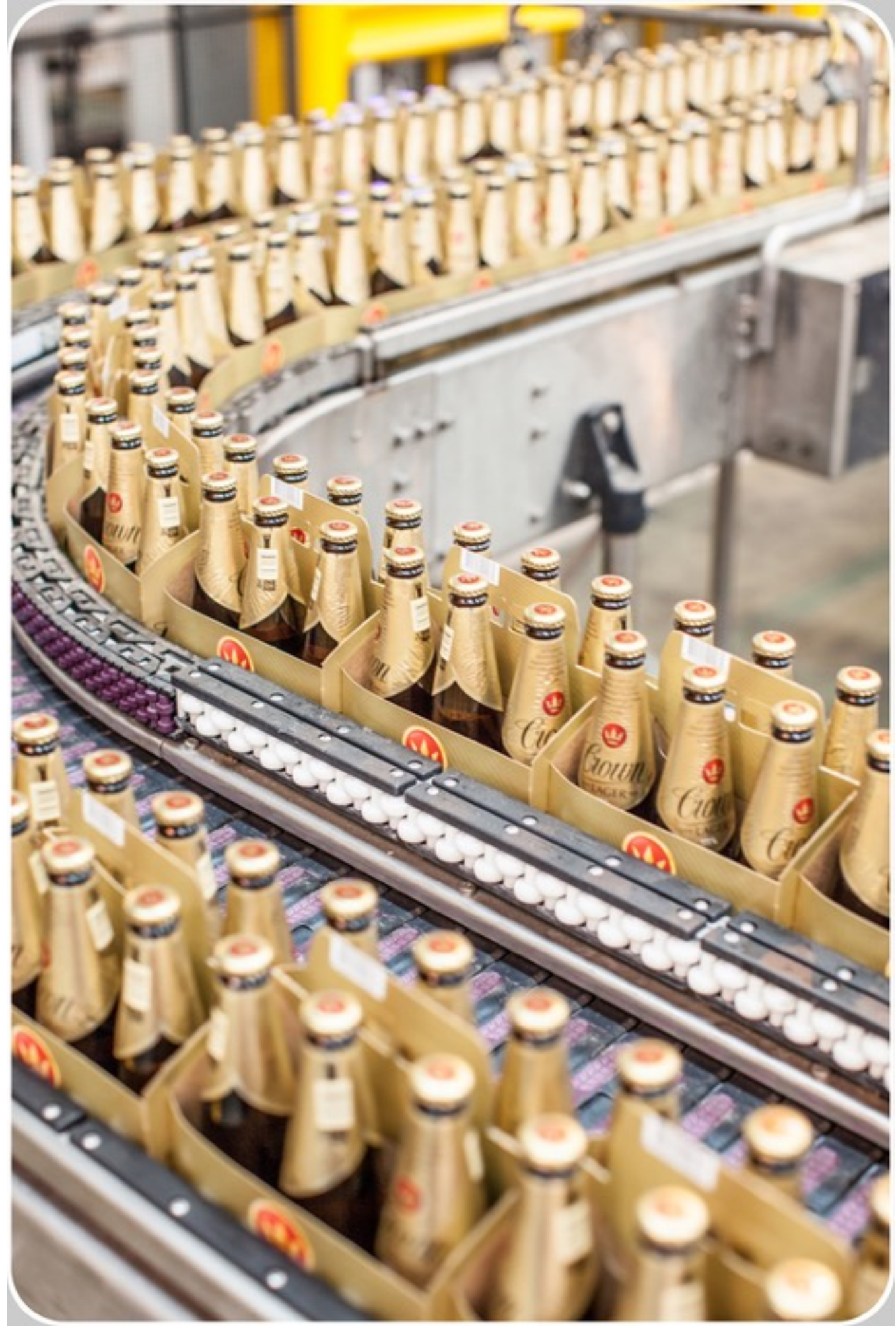
Then, the joint probability representing the Risk R that the five homogeneous systems (inspecting different projections of one and the same physical property, different sample spaces of the same state space) simultaneously fail to recognise one and the same defect, shall be limited to:

$$R_{1,\,2,\,3,\,4,\,5} = \prod_{i=1} R_i = 0.001\ \%$$

Meaning:

- that no more than 1 (one) non-labelled bottle in a row of 100000 non-labelled consecutive bottles out feeding by the Labeller Machine, shall not be detected defective by the Electronic Inspector, thus passing to the Market,
- detection ratio >99.998 %.

The detection of the flagging labels represents an area where the Probability Multiplication Theorem aids the Food and Beverage Quality Control. Greatly enhancing defects' rejection and reducing the false rejects. In the figure, the Yattala Brewery, Fosters Group and CUB, Australia, part of SAB MIller Plc (📷 Tom Parker/OneRedEye/2012)



False Rejects Ratio

We can look also on the other side, to the expected average value of the False Positives (false rejects) deriving by the superposition of the random variables measured by a Binary Classifier. We have immediately different possible approaches, corresponding to our own prudential choice. Choice referred to the level of confidence we attribute to the classification enacted by each individual Binary Classifier.

For the value expected by the sum (or, superposition) of N independent random variables, following the confidence we attribute to the outcomes of our measurements, we'll have at least three kinds of estimation:

1. *most prudential*
2. *prudential*
3. *less prudential.*

1. Imagine that we'd decide to adopt the *most prudential definition of sum* of N independent random variables, an Electronic Inspector (a Binary Classifier) composed by a set of N inspections whose individual rejects R_i converge to a single Rejector (or, ejector), each one identified by the suffix-i. In this case, the probability that each one of the N homogeneous inspections simultaneously and erroneously classify "defective" (False Positive) their physical measurements of a container has an upper bound which is their sum:

$$\sum_{i=1}^{N} Inspection\ reject_i$$

and, for i = 1, 2, …, 5 we'll have:

$$FP_{expected\ \%} < 0.05\ \%$$

2. Adopting the *prudential definition* of superposition of N independent random variables, we'll have a correspondingly ***best estimation of the expectation value*** for the total False Positives (false rejects) of the entire system of Binary Classifiers, as:

$$\sqrt{\sum_{i=1}^{N} Inspection\ reject_i^2}$$

which let us estimate the Total False Positives ratio as:

$$FP_{expected\ \%} = 0.022\ \%$$

3. Adopting the *less prudential definition* of superposition of N independent random variables, we'll have a correspondingly *estimation of the expectation value* for the total False Positives (false rejects) of the entire system of Binary Classifiers, as:

$$\frac{1}{N}\sum_{i=1}^{N} Inspection\ reject_i$$

implying an estimation of the Total False Positives ratio:

$$FP_{expected\ \%} = 0.01\ \%$$

Conclusions

Well before to mislabel 100 000 consecutive bottles, the Rejects Accumulation Table of the Electronic Inspector, should be fully occupied by rejects. The sensor of the Conveyor Control Cabinet managing this part of the Beverage Bottling Line, set in the Rejects Accumulation Table should control an automatic stop of the Labeller Machine.

The straightforward application of the frequentist definition of Probability, silently assuming an infinite capability to accumulate rejected bottles, is countered by a reality where the:

1. limited accumulation space, typically (80 - 300) standstill bottles, on the Rejects' Accumulation Table,
2. existence of a sensor to detect that status and controlling Labeller Machine stop.

Then, it is better to get out of that classic definition of Probability and modernise our idea of *expectation of the future Events* to the relatively modern Bayesian viewpoint. The expected Risk that a single non-labelled bottle pass to the Market, when consecutively inspected by five independent gaussian measurement systems, results still much lower than 0.001 %.

Case Study

Redundant inspection of Flagging-Labels



Is it reasonable to expect these excellent values for the losses (false rejects <0.022 %) and for the defects' detection ratio (>99.998 %) ?

Yes. We are using as a base for the following calculations a value for the Risk R = 10 % that a non-labelled bottles (equivalent to grossly-malpositioned label) is a False Negative. Then truly defective but not detected. The reality is that this 10 % is an excessively prudent one: missing labels are typically (2-sigma, 95 % of the cases) yet detected, leaving a Risk limited to <5 %. Banally, we preferred to use the most prudent possible 10 % to account for all possible kinds of labels. Thus including also the most difficult kinds existing: semi-transparents or transparents.

Is it technically feasible the solution in the scenario presented above ?

The answer is positive. Since 2008 it is being applied also in some particularly fast and multiformat Nestle' Waters® Bottling Lines, treating the wrap-around labels, like those shown in a figure here at right side. Applied in more than one factory to Flagging-Label inspection over PET-containers moving at speed > 1.7 m/s. We remember here that the coupling of a plastic bottle with a modern and typically-plastic wrap-around label, has plenty of esthetic advantages but is ill-fated when coming to the Electronic Inspection of the label.

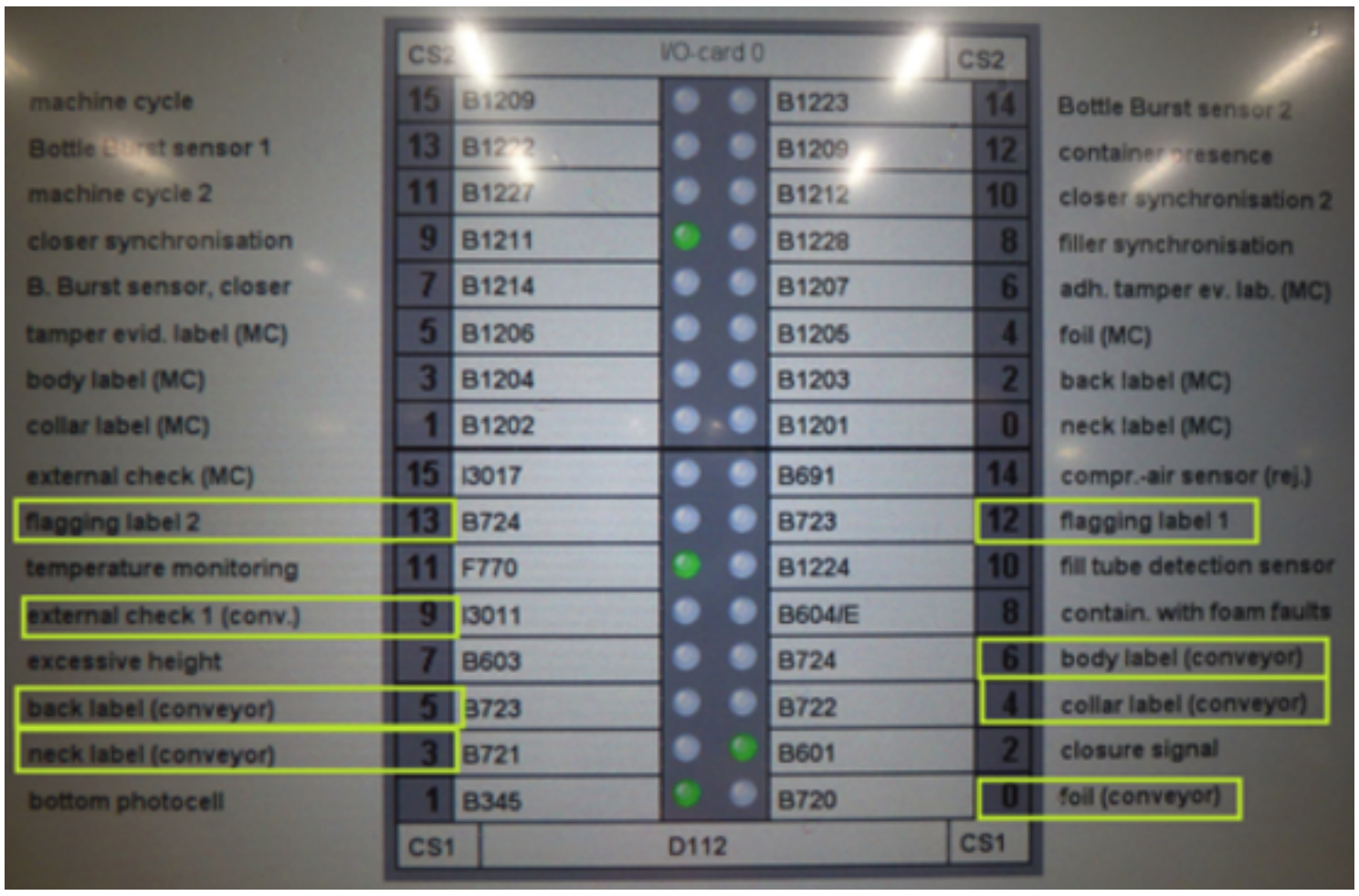


S. PELLEGRINO® mineral water in a glass bottle with paper label (NESTLE' WATERS®, 2014)

NESTLE' WATERS® AQUAREL. Yet in 2008 its production started to be deeply controlled for the presence of flagging labels, applying maximum redundancy to the inspection (NESTLE' WATERS®, 2014)

It provides *lower Signal-to-Noise* values to the infeed of the photoscanner's phototransistor, quite banally because the optic properties (refraction, reflection and diffraction) of the plastic bottles result not particularly different by those of the labels. Remaining in the sector of the mineral waters' bottling, think to the traditional application of a paper label over a glass bottle.

Refer now to the figure below. It shows the digital I/O card 0 (CS 1 and CS2) in one of the world's most common models of Electronic Inspector.



I/O card 0, CS 1 and CS2 in the world's most common model of Electronic Inspector has yet 8 digital inputs ready to apply label inspection photoscanners outputs, and its upgrade is then limited to a software enabling the display of the menus related to the additional photoscanners, fixing and photoscanners themselves

Within green coloured rectangles the 8 digital inputs ready to apply label inspection photoscanners outputs. In other terms, and with reference to one of thsie problems permanently affecting the beverage Bottling Lines, to prevent flagging labels, 90% of all of the type of defects getting out of Labeller Machines, from reaching the Market, does not require complex camera based systems. Hardware is there, waiting to be fully recognized in its usefulness.

What above is presenting a column of bold facts; facts where maximum Quality is obtained the lean-way jointly with maximum economy in:

1. an Electronic Inspector of the best Quality existing in the World, costing total 30000$ (or, 25000 €),
2. equipped with five photoscanners of the best Quality costing <260 $/each (<230 €/each) and easily available,
3. checking Label Presence *at-the-Conveyor*,
4. costs in the end an amount which is four times less than a camera based final inspection system (~100000 €),
5. reaching withiut any effort inspection performances on the Label Presence inspection close to those reached for the same kind of defect (missing or grossly-misplaced label) by the camera-equipped systems,
6. with a lower False Reject ratio, then lower losses on Production,
7. does not need the Advanced Training of the Electronics Maintenance Dept. technicians of the Bottling Plant, vital to assure constancy of the performances of the camera-equipped models, curbing the natural tendency of the camera-equipped models to increase their False Rejects' ratio,
 1. presents a Total Cost of Operation (TCO, futher informations here) much lower

than the camera-equipped models:

1. all changeovers can easily be made by the Electronics Maintenance Dept. technicians of the Bottling Plant,
2. there are not inspection protective panes nor strobo flashers to replace,
3. proper maintenance, keeping apart rare cases of hardware fault, can always be assured by the Bottler's Staff.

Links to the other pages:



Where to establish a correlation The best place to control labels' application is in-the-Labeller Machine, thus having the possibility of an early warning about the typical issue affecting all



IntroductionThe interaction of a material irradiated by electro magnetic waves, implies three different effects: reflection, refraction and diffraction. Light irradiated by a LED most commonly operating infra-red (IR) at a wavelength of ~1µm, or visible red colour (see figure



Today all Vendors have unified the main design for all-around (360º) CCD-camera equipped inspection of bottles' sidewall, necks and finishes (labels, fill level and closure), in a stainless cabinet

- Label Presence inspection in-the-Machine
- Label insp. at the Conveyor, analog sensor
- Label insp. at the Conveyor, with camera
- Label inspection .pdf
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Graphene®

Food and Beverage Electronic Inspection Experts



Today all Vendors have unified the main design for all-around (360º) CCD-camera equipped inspection of bottles' sidewall, necks and finishes (labels, fill level and closure), in a stainless cabinet which can be opened for maintenance on both lateral sides and by the top with bottles passing through

Introduction

A real jump-up on Label Inspection performances is obtained when changing technology from Photoscanners to Machine Vision. Reason is the much greater amount of Information about the label properties that it results possible to register with a camera. Amount established correlating a label with hundredths of thousands (or, millions) of individual photo-detectors, rather than just one. The figure above shows an example of the equipments' for final inspection using CCD- or CMOS-technology cameras to inspect the labels' presence and position. At left side, a typical example of labelling where Machine Vision becomes nearly unavoidable.

Label Inspection



(label_inspection.zip)

Flash animation, 45 MB, ZIP

After download click index.html

What performances



The performances to expect depend on:

- the optic configuration,
- amount of cameras,
- eventual adoption of Artificial Intelligence algorithms,
- amount of CPUs devoted to the task or, availability of GPUs.

In the fast Labeller Machines >50000 bottles-per-hour the Collars missing and mal-positioned, account typical rates as high as ~80 % of the total rejects, with missing and malpositioned Body and Black labels summing up to the remaining ~20 % of the detected defects (📷 CARLSBERG Group, 2014)

Download PDF

(label-inspection-.pdf)
(../../../designer-portal/root-cause-analysis/root_cause_analysis_problem.pdf)

59 pages, 71 MB

(label_inspection-2.epub)

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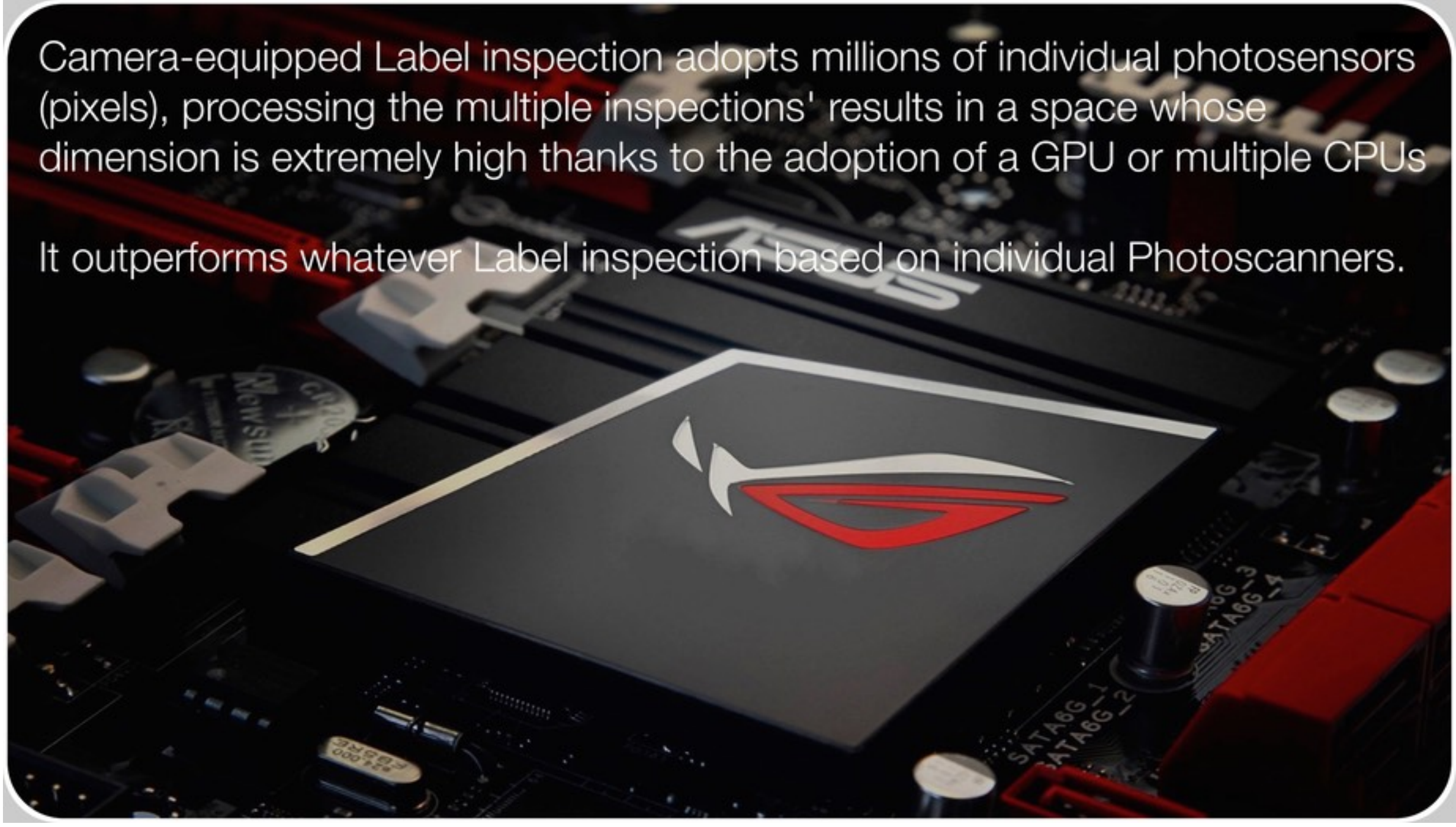
E-book 59 pages, 41 MB

As an example, for the final inspection equipment depicted above, they are close to:

- (1.0 ± 0.1) mm *malpositioned labels*, detected at >96 % with associated false reject ratio < 0.01 %,
- *missing-* or *flagging-labels*, detected at >99.5 % with associated false reject ratio < 0.01 %.



To detect the entire external sidewall of the container, means to use two CCD- or CMOS-cameras equipped with some megapixels each. Notoriously, each pixel emulates an elementary (passive-only, no light source) analog photoscanner, whose dynamical range following its model ranges today (4096 - 65535) grey levels. By these digits, millions of individual analog photo detectors, and the fact that from each one we are capable to discriminate thousands of grey levels, it is easy to infer why the performances jump-up from the mere presence or absence of a label detectable with a single photoscanner, to positions whose accuracy level rounds 0.1 mm.



Collars, Neck and Foils: Machine Vision shows its best

Collars, like those visible in the figure below shot at a SABMiller® PLC Brewery in Colombia, when flagging are a typical challenge fronted daily in the breweries. impossible to counter with a single Label Presence photoscanner in-the-Labeller Machine. On the opposite, a truly easy application where the same defect is detected by mean of Machine Vision in an external final inspection system at-the-Conveyor.

In today's fast (>50000 bottles-per-hour) rotary Labeller Machines, the missing plus malpositioned collars account typically for ~80 % of the total rejects, with missing and mal positioned Body and Black labels summing up to the remaining ~20 % of the detected defects. One of the reasons lies in the difficulty to label the most curved surface of the bottles' external sidewall. Also, a non-cylindrical shape, rather a conical section. Same is true also for the Label Presence inspection *in-the-Labeller Machine.*

It'll be established a correlation of the shortest duration between the single photoscanner and label, in an area of the bottle so curved to result unavoidably that one featuring the highest luminous diffusion, due to known laws of Geometric Optic. Then resulting a minimum for the luminous re-emission infeeding photoscanner's phototransistor.



A transparent self-adhesive label. Its reflective area reduced to a very small text and logo. An application prone to cause false rejects yet adopting the best and most modern photoscanners today existing. A natural application for camera-systems



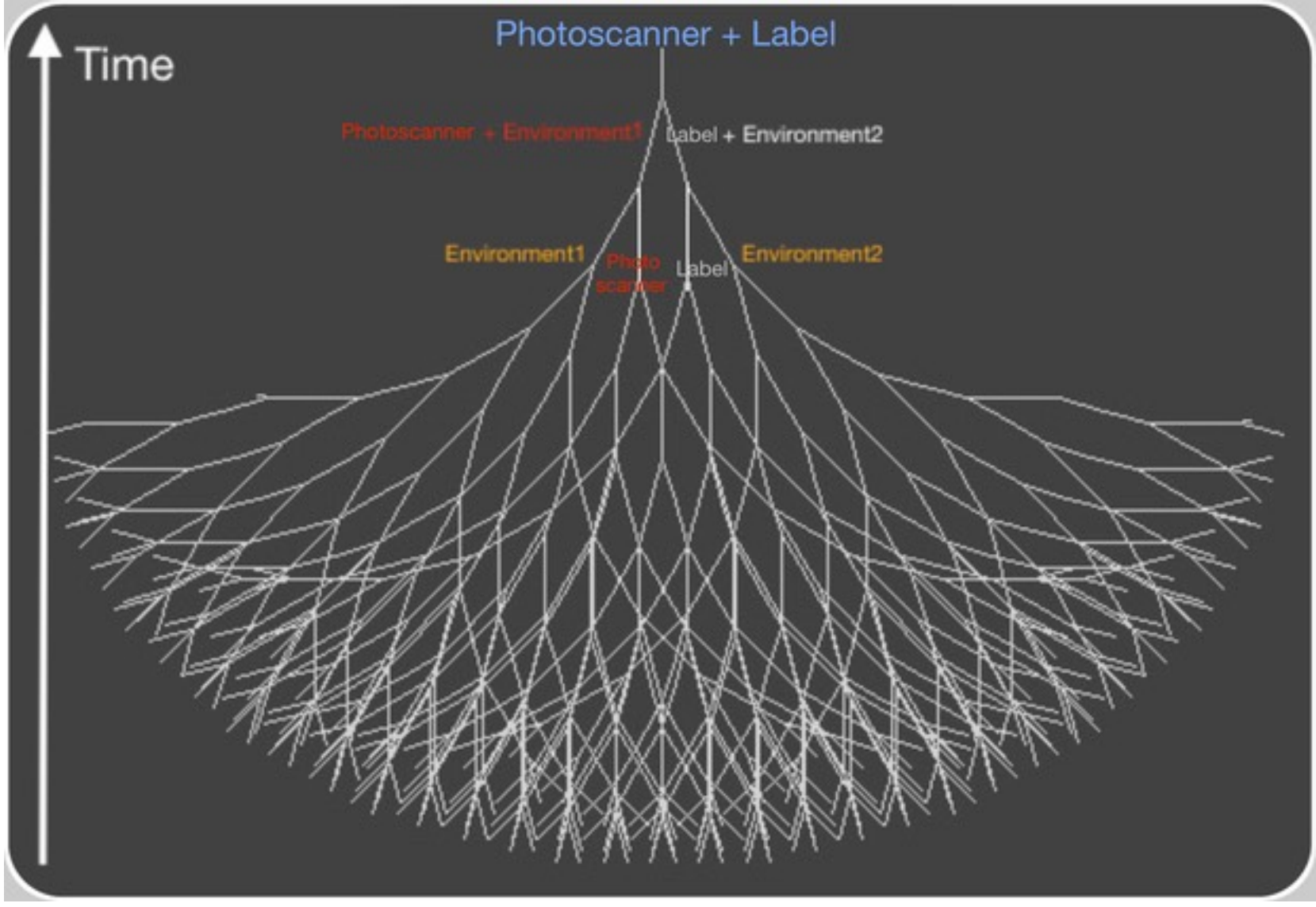
Flagging Collars are a typical challenge impossible to counter with a single Label Presence photoscanner *in-the-Labeller Machine*. On the opposite, an easy application where the same defect is detected by mean of Machine Vision in an external final inspection system *at-the-Conveyor*, in this image shot at a SABMiller PLC Colombia, Grupo Bavaria (📷 Tom Parker/OneRedEye/2012)

What is a “good Label inspection” ?

The correlated Label-Pixel State

As we saw with plenty of details elsewhere in this web site (../../../services--technologies/physics-of-triggering/Trigger-Physics/index.html), as an example we’ll try to determine if a bottle is labelled by mean of a system like a camera, including millions of Pixels. Pixels accumulate one-by-one the photons reflected by the sidewall, neck and closure of the bottle. Later discharging the potential accumulated to an A/D converter whose outfeed is sequentially read by following circuits to deduce what to a level of illumination has been subjected each individual pixel during the limited exposure Time. [There are particularly fast Electronic Inspectors, adopted to inspect plastic empty bottles, having the exposure Time of the Pixels in their cameras forcedly limited to tens of microseconds…]

To establish a relation between a label (“Label”) and a Photoscanner (“Photoscanner”), both differentially related with the Environment (“Environment1”, Environment2”), is necessary Time. Time to transform the previous *state*, in which all possible kinds of correlation of the



Photoscanner coexist, in a following *state* in which the Photoscanner is "aware" to be correlated to a label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a cap. Quantomechanical explanation of the measurement process, unaffected by the circularities implicit in the classic explanations. The vertexes represent *interferences*

To definetely perceive a *correlated Label-Pixel State*, they are necessary:

1. **Time, to transform the previous state, in which all possible kinds of correlation of the pixel coexist, in a following state in which a camera inspection is "aware" to be correlated to a Label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a Label.** The correlation between the two systems, camera inspection and Label, is progressively established during interaction and proportional to the natural logarithm (ln t) of the interaction time t. An ideal correlation, one corresponding to a maximised information of the inspection about the Label, can only be reached allowing an infinite time. The fact we cannot wait for an infinite time causes the measurements' fluctuations, a synonimous of the spectrum of the eigenvalues, resulting in the Electronic Inspector's false positives (false rejects). Time, for what ? To transform the previous state, in which all possible kinds of correlation (superpositions) of each one of the many pixels composing a camera sensor coexist, in a following state in which the inspection is *aware* to be correlated to a Label, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing a Label by the camera pixels;
2. **Interaction between the systems such that the Information in the marginal distribution of the object inspected is never decreased**. In a probability distribution deriving by two random variables, we remember that *marginal distribution* is where we are only interested in one of them. Otherwise, we'd have forced a reduction in the sample space of one of the random variables and then, we could not have any more *repeatability* of the following measurements. As an example, this should be the case if to interact with the Label we'd erroneously try to use a beam of high energy neutrons, rather than strobo flashers' or LED-matrices's low energy photons. The neutrons should modify the molecular structure of the Label, modifying its eigenstates and then the eigenvalues we expected to derive by the measurement.

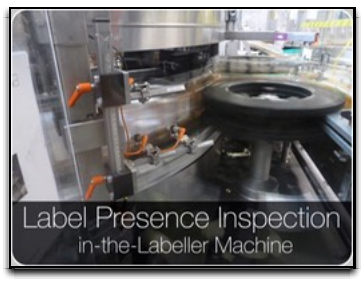
To detect a Label they are necessary Time and a kind of interaction which do not reduce the information in the marginal distribution of the Label. The second requirement is always fulfilled in the Electronic Inspectors but a real problem exists in relation to the first, depending on design choices of the Labeller and of the Bottling Line layout (📷 CARLSBERG Group/2014)



SABMiller PLC, Kompania Piwowarska, at Poznań, Poland (📷 Tom Parker/OneRedEye/2012)



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Where to establish a correlation



IntroductionThe interaction of a material irradiated by electro magnetic waves, implies three different effects: reflection,



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